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~~VERTICAL SENSOR TECHNIQUES PROGRAM~~

(6) DEVELOPMENT OF AN ATMOSPHERIC SOUNDING DROPSONDE, GROUND RECEIVING AND DATA PROCESSING STATION.

FIELD TEST REPORT.

(10) by R. A. Mullen and
J. E. Lynott,

(11) Feb[redacted]65,

[redacted]

(15) Contract [redacted]. AF 33(600)-41821

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FOREWORD

This report is the final summary report on the work carried out during the Vertical Sensor Techniques program, Contract No. AF 33(600)-41821. During this program, sensing techniques were developed for measuring four atmospheric parameters. The four parameters are atmospheric pressure, index of refraction, dewpoint, and ozone concentration. The techniques developed are applicable to use in dropsondes and rocketsondes. Detailed descriptions of all aspects of development, design, and laboratory and environmental tests of these sensing techniques have been described in earlier Technical Notes.

ABSTRACT

This report includes a general summary of the entire program and detailed summaries of all phases of the program not covered in the earlier Technical Notes. Specifically, the design and testing of the balloon-lifted dropsonde field test vehicle used in the flight demonstration of sensor feasibility is described, along with the mobile field telemetry station associated with the dropsonde in the field test. The field test is described and the resulting data analyzed. Conclusions regarding the degree of success achieved in the sensor development are ~~detailed.~~ described. Problem areas remaining for the application of the sensing techniques are noted. Future actions to utilize the techniques developed are recommended.

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SECTION 1

INTRODUCTION

This final report documents the Bendix Research Laboratories Division's (RLD) effort on the Vertical Sensor Techniques Program, Contract No. AF 33(600)-41821. The program essentially covered design of the test dropsonde and telemetry and data handling system and field flight tests.

The work performed on the individual sensors has been previously documented, along with an Operation's Manual for the trailer mounted ground station. These documents are as follows:

(a) Development of an Index of Refraction Sensor for Atmospheric Sounding, Bendix RLD Report No. 2057.

(b) Development of an Ozone Sensor for Atmospheric Sounding, Bendix RLD Report No. 1998.

(c) Development of a Hypsometer for Atmospheric Sounding, Bendix RLD Report No. 2056.

(d) Development of a Dewpoint Hygrometer for A Atmospheric Sounding, Bendix RLD Report No. 2055.

(e) Operations Manual, Telemetry Ground Station for Meteorological Data Handling, Mobile, Bendix RLD Report No. 1949.

The assembling of sensors, transmitter, commutator, and battery pack are treated in this report, along with the problems that were presented. Most of the problems encountered fall into the following three broad categories: aerodynamics, packaging, and testing. The first two categories are interrelated, such that whatever is determined aerodynamically about the sonde generally affects the packaging of the assemblies, and conversely the actual placement of certain assemblies generally affects the aerodynamics. The obvious need of the third category only underlines the necessity of compromise which exists between the first two categories.

Although chronologically the solutions to the aerodynamic problems and the packaging problems of sonde assemblies occurred simultaneously, they are discussed as separate entities in this report. The test and test results are discussed with whatever subject they are associated.

SECTION 2

DESIGN CRITERIA

2.1 AERODYNAMICS AND TEST PROFILE

The contract firmly established balloon flights as the method of flight testing the sensors. To generate a balloon flight profile it was necessary to set up certain rules. They are:

(1) Sensor measurement and sampling takes place in the descent portion of the flight only.

(2) The duration of the entire flight must not be long enough to allow the vehicle to drift out of range of the telemetry system.

(3) An altitude of 100 thousand feet, if attainable by the required balloon, is very desirable for certain sensor measurements.

(4) The outside diameter of the sonde package was fixed at 4 inches. This was done in order to maintain sensor size consistent with general purpose rocketsonde use.

A flight test profile report was issued in the Monthly Progress Report of December 1960. A summary of the flight profile is listed below:

Ascent Time	2 hours
Maximum Altitude	100,000 feet
Horizontal Drift During Ascent	80 miles
Descent Velocity at 100,000 Feet	460 feet/second
Descent Velocity at Sea Level	50 feet/second
Time of Descent from 100,000 Feet	20 minutes
Horizontal Drift During Descent	20 miles
Total Horizontal Drift from Launch Point	100 miles
Dynamic Pressure (q)	2 millibars

In the above, "q" is defined as the difference between total pressure and static pressure and is based on the fact that the parachute will act as a

nearly constant pressure device. Other points in the summary are self explanatory and were intended to stay within the aforementioned ground rules.

With the determination of a flight test profile, work was then started on aerodynamically determining the pressure port sample, the accuracy with which the sample flows in the ducts, and their time lag. Here again, the initial work on these subjects was reported in the Monthly Progress Report, of December 1960. The results are summarized below:

The static pressure ports are located approximately 5 diameters back from the front of the sonde. The deviation from static pressure at this location is approximately 0.5 percent of "q." Other factors affecting the measurement of static pressure are angle of attack, hole size, and hole edge treatment. The three factors contribute an inaccuracy of about 4 percent of "q" with the total being 4.5 percent of "q." This gives an approximate error in altitude of 1 percent at 100,000 feet with the corresponding relative error becoming less as static pressure increases.

Sampling errors related to dewpoint were also examined with respect to the pressure at which the sample is measured. Selecting the worst case of minimum pressure (100,000 feet), highest dewpoint to be encountered (ARDC Extreme T), and an uncertainty in pressure measurement which is then related to an uncertainty in water vapor pressure, the maximum uncertainty expected is 1.8 degrees Centigrade. The sample flow for the dewpoint sensor will be discussed later.

In the Index of Refraction sampling, pressure again causes an uncertainty factor as given by

$$N = \frac{77.6}{T} \left[P_s + 4810 \frac{e}{T} \right]$$

where P_s and e are in millibars and T is in °K. Studies, as explained in the AN/AMQ-15 Air Weather Reconnaissance System AF 33(600)-37984, Final Report No. 1319, indicate that between sea level and 50 K feet the total uncertainty in "N" resulting from a 2 millibars pressure uncertainty is 0.5 N units. These calculations assumed a 50 percent relative humidity and included the effects of pressure change on vapor pressure and humidity.

With the report on the flight profile and suspected sampling errors, a tentative package layout was provided. This layout showed the method of sampling for each of the sensors. Dewpoint, Index of Refraction, Ozone, and Temperature all received their sample from the front face of the package. The pressure ports, as stated earlier, were located 5 diameters from the front face of the sonde. The index of refraction tube was routed through the entire package and exhausted in the rear, with the temperature sensor mounted in the inlet of the index of refraction sample tube. The dewpoint sample tube started at the front and exhausted through a series of vent holes four inches back from the front.

During the first four months of 1961 changes in th design of sensors caused a design change in the sampling technique for the package. In May an outline drawing of the package as it is today was issued. Because of the changes in the sampling systems, a consultation with the Flight Science Group of Bendix Systems Division was held. The entire package-parachute system with the various sampling systems was investigated by them. In this configuration (see Figure 1) the index of refraction sample exhausts through porting holes approximately 12 inches from the front. The dewpoint sample, after passing the mirror assembly, immediately exhausts against the electronics heat exchanger. The pressure sampling port is moved to a position five diameters back of the exhaust of the index of refraction sensor.

Conclusions from this meeting were as follows:

(1) The parachute-sonde system is stable. Reference literature shows the system to be over-damped when the parachute-to-load separation is less than 300 feet. The parachute under discussion is the guide surface type.

(2) Location of the static pressure sampling port is reasonable. Here again reference to tests conducted on a blunt nose body show that with this location the maximum sampling error will be approximately 0.1 millibar.

(3) The over-all package is aerodynamically sound.

2.2 PARACHUTE

As a result of the above conclusions, parachutes were ordered with the following properties:

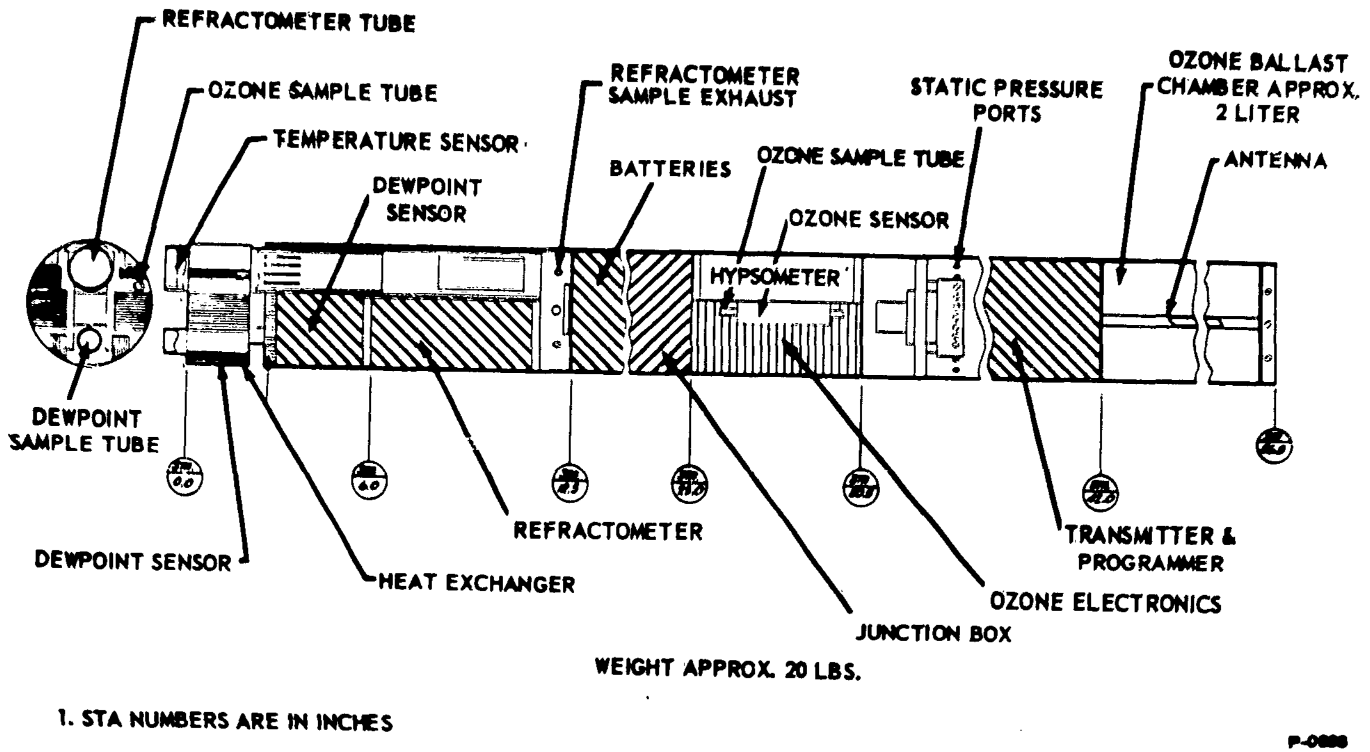

Figure 1 - Outline Drawing of VST Sonde Model 1

(a) Ribless guide-surface parachute, silvered nylon material

(b) Stability, 5 degrees

(c) Diameter, approximately 3.75 feet

(d) Estimated sea level fall velocity, 45 $\pm$5 fps (with a 25 pound load)

(e) $C_D A$, approximately 6.3 square feet

(f) Attachment cord at top of canopy, three leg bridle for attachment to sonde, swivel at confluence point.

2.3 AIR VELOCITY SENSOR

The necessity of knowing whether there is any air flow in the ducts is obvious. To determine this, an air velocity sensor was developed and tested. This sensor consists basically of a bead thermistor wrapped with a heater coil. The assembly is heated in the air stream while a second un-heated thermistor is subjected to the same air stream and installation environment. The temperature difference between these two thermistors is an indication of mass flow rate.

Several experimental models (Figure 2) were built. Tests were performed to ascertain the optimum heater power to be used and to observe the high altitude performance. Good resolution was obtained with 20 milliwatts dissipated in the heater of the sensor. The sensor was tested in a 3/16 inch flow tube using a Hastings flowmeter for comparison. The thermistor air velocity sensor showed accuracy within $\pm$20 percent up to an altitude of 80,000 feet without altitude correction. Partially smoothed calibration data for one sensor is presented in the August 1961, AF 33(600)-41821, Monthly Progress Report. A second unit which was calibrated at the same time yielded nearly identical results.

It was anticipated that in actual use the effects of calibration error, radiation error, heater drift, and telemetry error would restrict the accuracy to approximately $\pm$25 percent. This was considered adequate for obtaining general information concerning air flow in the index of refraction and dewpoint ducts during drop tests.

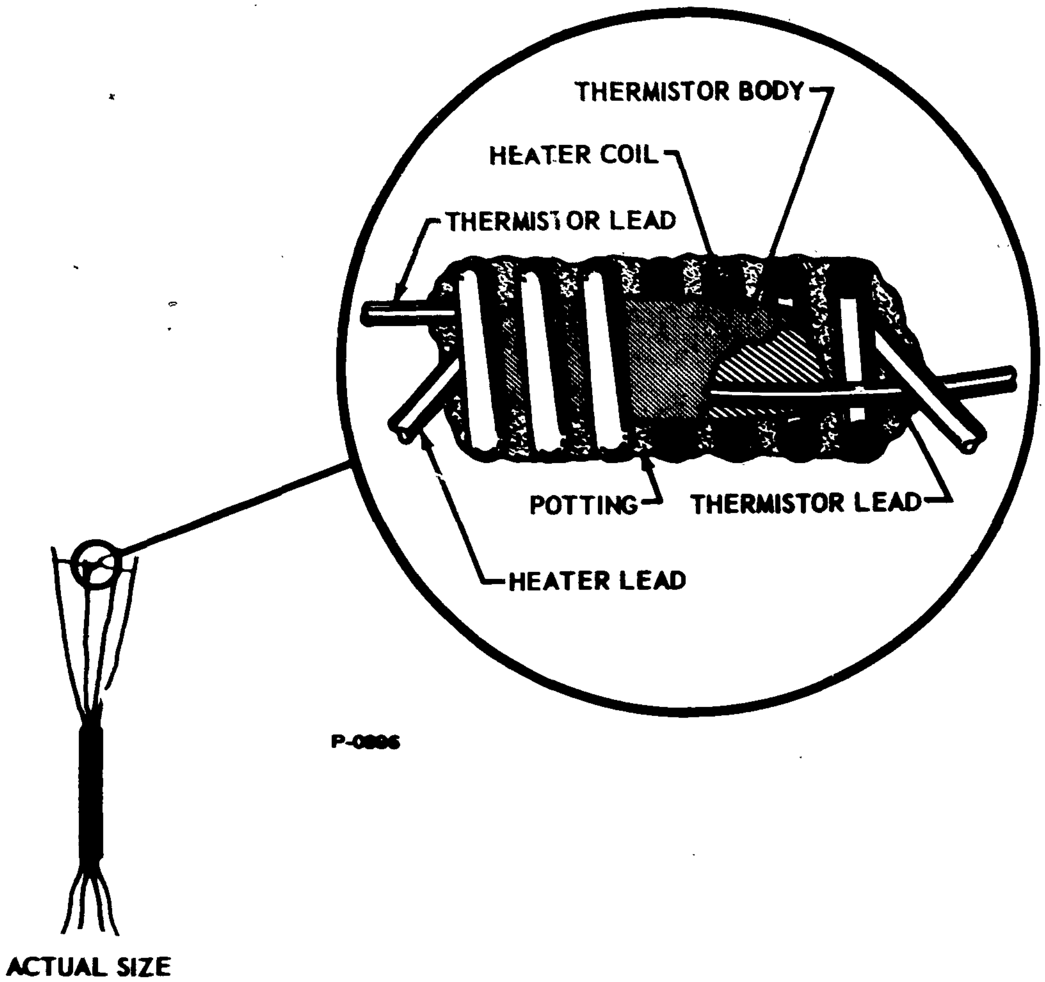

Figure 2 - Air Velocity Sensor

SECTION 3

PACKAGING

3.1 SENSOR LOCATION

Initial efforts in constructing a sonde package started in December 1960. Enough work had been done at that time on each of the sensors to establish the various voltage levels to be used throughout the package. These were subject to revision depending upon sensor development; however, no revisions were necessary.

Initial placement of sensors and other components were reported also in the Monthly Progress Report of December 1960. In this layout the dewpoint sensor and the ozone sensor were located in the extreme front end. In fact, the slit for the ozone sensor sample inlet opened on the front end. However, as development of the dewpoint sensor progressed, the need for a large surface area for cooling of the Peltier junction became evident. Also, it was advantageous to move the ozone sensor further back since the film reaction rate is temperature dependent. Thus, the ozone sensor was moved back with the ozone electronics and the whole frontal area of the sonde, and except for the index of refraction and ozone sampling tubes, was devoted to dewpoint.

3.2 SAMPLING METHOD

An alteration was made in the index of refraction sensor sample method. The initial placement of the sample tube associated with index of refraction ran the full length of the package, exhausting in the rear of the sonde. It was felt that placing the exhaust of this sample immediately to the rear of the sensor would conserve space formerly occupied by the sample tube throughout the rest of the package. In addition, the dewpoint Peltier high current batteries were included with the rest of the battery pack. This made it possible to move the index of refraction sensor forward adjacent to the dewpoint electronics. Thus the index of refraction sample exhausted approximately twelve inches from the front through port holes in the skin.

The requirements of the ozone sensor made it mandatory to provide space for a 2-liter volume to act as a ballast tank, or constant volume device, which was also designed to include the telemetry antenna.

3.3 SENSOR INTERCHANGABILITY

As a basic design consideration, packaging of the four sensors was intended to be such that any or all of the sensors could go into the same sonde package. The reason for doing this was so that during the first flights one or two sensors could be flown and as testing continued more sensors could be added as they individually proved themselves. However, in sending sondes into the field it would be difficult to assign sensors irrevocably to a given package during the interval between initial testing to the point where all sensors would be flown. Thus, with the capability of flying any combination of sensors, changes could be made in the field to add or take out individual sensors.

To effectively make changes in the field, it became necessary to build a junction box (Figure 3) to facilitate: (1) removal and replacement of a defective sensor, (2) addition of a sensor, (3) change or replacement of the test points and outputs of sensors going to the commutator, and (4) effective distribution of battery voltages.

The use of a junction box required that the package be broken into sections with each section having connectors, with each connector or sensor plugging into the junction box. There are seven connectors used all together, going to Dewpoint, Index of Refraction, Battery Pack, Transmitter, Ozone-Hypsometer, and two connectors to the commutator. The junction box consists of two terminal boards and space for mounting seven connectors. One terminal board has all points from the connectors attached to it and is used to: (1) distribute battery voltages and (2) cross strap the monitored voltages to the commutator channels. The other board is utilized to mount resistors used in the divider networks for the

Figure 3 - Junction Box

Figure 4 - Battery Package

carbon humidity element, baro-activated pressure sensor, temperature sensor, etc.

3.4 POWER REQUIREMENTS

The battery pack (Figure 4) consists of those batteries necessary to provide the following power:

±15 V @ 1 a

±19 V @ 100 ma

+ 6 V @ 5 a

The following batteries are used with the dewpoint sensor only:

+1.5 V @ 2 a

+1.5 V @ 5 a

+1.5 V @ 20 a

+1.5 V @ 2 a

Temperature tests were conducted using a complete set of batteries in an effort to determine the amount of heating necessary to maintain the battery pack at -10°C. The batteries were mounted in a 4-inch phenolic tube. A maximum of 10 watts was needed during a one-hour run with the ambient temperature at -60°C. Ten-watt heater blankets were purchased together with -10°C thermostats. The test was then repeated with the thermostat using a duty cycle of 50 percent.

3.5 COMMUTATION OF DATA AND ENVIRONMENTAL TEST

The commutator used with the sonde package has 24 channels, with each channel preceded by an identification channel. Sample commutator boards were obtained from Bendix Friez Division along with several Brailsford commutator motors. An assembly consisting of a board, motor, and wiper arm was tested for contact bounce at a 10 rpm commutation rate with a dwell time on a value segment of 1/4 second. This assembly was tested as the wiper arm contacts moved along the surface of the commutator board by using an oscilloscope. No contact bounce was observed at the 10 rpm rate; however, observation of contact bounce on the identification segments was very difficult because the on-time was so short. In order to observe this the commutator assembly was electrically connected to the breadboard transmitter, and no changes in the identification frequencies were observed.

After the above test was completed, the commutator assembly was tested in an environmental chamber. At room temperature, the wiper arm rotated at 10 rpm; at -20 °C the room ambient pressure the motor would not start. At this point the commutator assembly was taken out of the test chamber and the housing on the motor gear train was removed. The gears were found to be lubricated with a rather heavy grease. The gears were degreased and lubricated with Hamilton Watch Oil No. F3358. The commutator assembly was returned to the environmental chamber and operated at 7.5 rpm after one hour soaking at -60 °C and a pressure corresponding to a 100K feet altitude. A second commutator assembly was subjected to the same test, and the same observations were made as with the first assembly before degreasing. The remaining motors were returned to the manufacturer for proper lubrication.

3.6 TRANSMITTER

The output requirements of the sonde transmitter are dictated by the sonde receiver and the sonde decoder, which are both part of the Ground Station Equipment. The requirements are:

(1) Transmission carrier frequency range is 400 to 406 megacycles.

(2) Deviation from center carrier frequency is plus and minus 0.75 megacycle.

(3) Form of transmission is pulse burst of carrier frequency energy of 15 to 20 microsecond duration.

(4) Transmitted information is contained in the pulse repetition rate.

(5) The repetition rate or period between pulses determines whether the transmitted data is an identifier or value parameter. The identifier is contained within a range of time intervals of 40 microseconds to 635 microseconds, and the value parameter is contained within a range of 640 microseconds to 10.235 milliseconds.

3.6.1 General

As outlined in the Vertical Sensor Techniques, Proposal No. 668, submitted April 29, 1960, the output information from all sensors falls in a range of zero to one volt. These requirements thus define the input to the transmitter and its output.

Also in the proposal, loading of the transmitter antenna as experienced in the AN/AMQ-15 program was discussed. It was proposed that a separate class C amplifier be used to drive the antenna and minimize the antenna loading problem. Several different types of r-f sections were examined among which were:

(1) that used in the AN/AMQ-15 design,

(2) the design used in the AN/AMT-6,

(3) a separate oscillator and class C final amplifier.

The result of this was the construction and testing of two prototype r-f sections which could be driven by the same modulator.

One unit was of the single tube keyed oscillator type while the other was a two-tube class C grounded grid power amplifier type. Under test, both units appeared to put out the same amount of power and both exhibit the same amount of frequency drift with respect to time. The two tube r-f section,however, was insensitive to the loading of the antenna caused by the proximity of metallic objects. In view of the fact that such loading of the antenna would not occur with the proposed flight plan, it was decided to utilize the single tube version, as shown in the block diagram, Figure 5, in all transmitters, as it afforded a

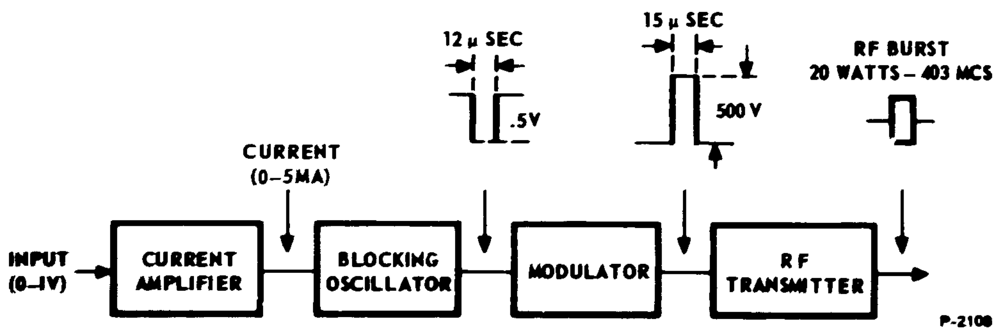

Figure 5 - Block Diagram Sonde Transmitter

reduction in cost. This decision was made only after both types of units were flown under field test conditions.

3.6.2 Basic Design

The transmitter assembly consisted of a current amplifier, blocking oscillator, modulator, and r-f transmitter.

The function of the current amplifier is to convert the sensor output voltage into a current which discharges the timing capacitor of the blocking oscillator. The blocking oscillator pulse characteristics defines the transmitter pulse duration, and converts the sensor output into a pulse repetition frequency analog It also develops sufficient output power to drive the modulator, which amplifies the pulse power and voltage and supplies plate voltage for the r-f oscillator output tube.

Several pulse transformers for use in the blocking oscillator circuit were analyzed and were found to have a pulse output voltage which varied with temperature and could cause frequency shifts in the output oscillator. The circuit was improved by using low output impedance wiring on the blocking oscillator transformer so that the pulse voltage varies only 0.4 volt in 300 volts over a temperature range of +25 °C. This variation was less than the variation to be expected due to supply voltage changes.

3.6.3 Identification and Value Pulsing

A means of generating both identification and value pulses with the same blocking oscillator circuit was devised. In this scheme, the commutator switches fixed resistors into the circuit when identification pulses are required. The identification resistors produce the desired identification pulse rate and are capable of over-riding any other frequency control present. When the commutator identification segment is disconnected, the previously suppressed value input voltage again becomes effective and a value pulse frequency is generated.

The single tube keyed oscillator sonde transmitter (Figure 6) was tested for frequency variations with respect to changes in filament voltage, plate voltage temperature, and antenna loading. The effects of the first two were found to be negligible. In the initial packaging of the r-f oscillator, the plane of the tank circuit was made perpendicular to the antenna axis to conserve space. However, frequency shift due to proximity of nearby objects became more pronounced than in previous designs.

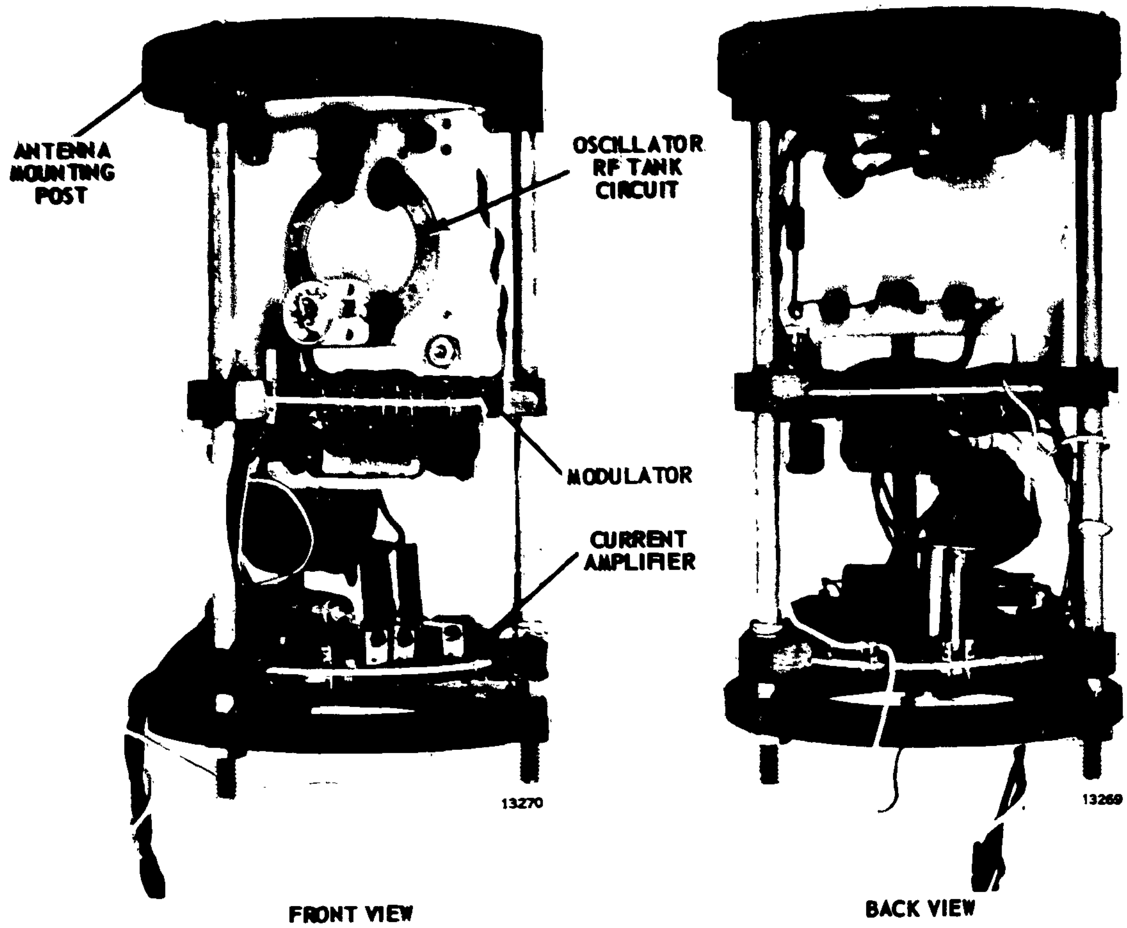

Figure 6 - One-Tube Transmitter

From this it was determined that when the plane of the oscillator tank circuit was made parallel to the axis of the antenna, the shift was reduced considerably. The r-f section was then repackaged with the oscillator parallel to the antenna axis and was tested satisfactorily.

At this point modifications to the modulator section were necessitated by the following reasons: (1) limitation of the value frequency from the blocking oscillator to a maximum of 1.6 kc to prevent confusion with the identification frequencies, and (2) switching of the index of refraction sensor output to by-pass the voltage-to-frequency conversion stage. The reason for the second requirement was that the output of the refractometer sensor is a frequency which changes

proportionally to the changes in the index of refraction. In this case the blocking oscillator in the transmitter is converted to a monostable oscillator, and the frequency output of the refractometer (properly scaled) then modulates the transmitter through the monostable oscillator circuit. The necessary switching operation is accomplished through the use of a diode logic circuit and the control voltage on the commutator segments assigned to activate the refractometer output.

3.7 ANTENNA AND BALLAST CHAMBER

The transmitting antenna used in the sonde package is one-half wave length, voltage end fed, and consists of a silver plated brass tube. The omnidirectional radiation characteristics of this antenna provides receptive capabilities at all times except when the sonde is directly above the receiving antenna. The ballast volume, which encompasses the antenna as explained previously, is a 2 liter size to meet the anticipated requirements of the ozone sensor. This ballast volume is constructed so that if at any time it is no longer required, opening a venting port allows the sampled air to flow freely through the sonde.

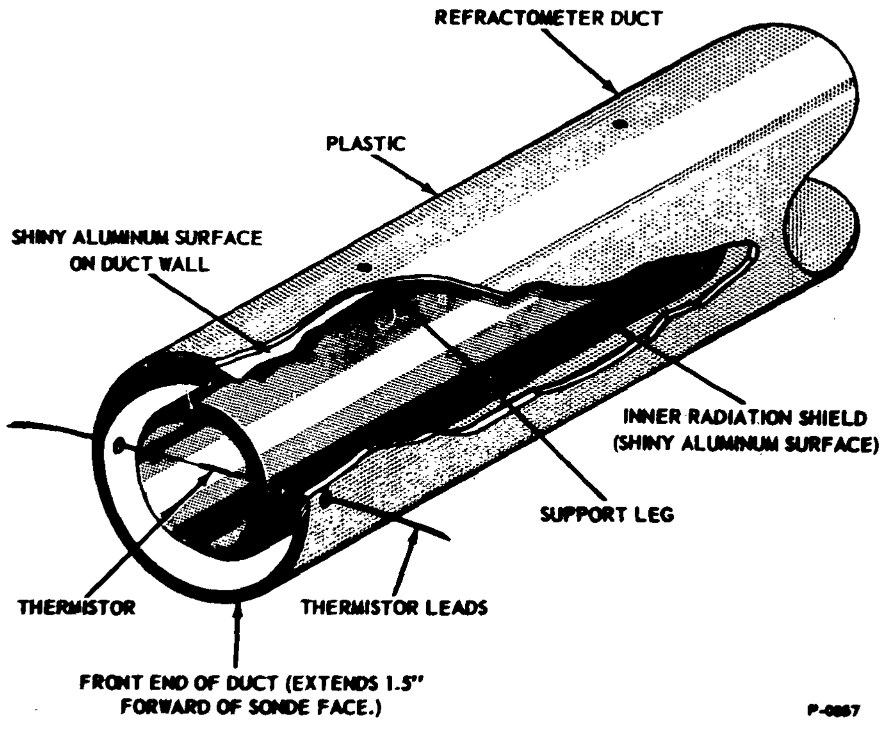

Figure 7 - VST Test Sonde Temperature Sensor

3.8 TEMPERATURE SENSOR

The temperature sensor (Figure 7) is basically a thermistor mounted in a cylindrical reflective shield and located in the front section of the refractometer sample inlet tube. The reflective shield is made of hardened aluminum foil and bonded together with aluminum solder. This aluminum structure is used to minimize conduction errors and time constants. Physically, the sensor consists of an aluminum-coated thermistor suspended by its leads at the center of a thin wall (0.002 inch) cylindrical aluminum radiation shield. This unit is then mounted in the above mentioned sample tube.

The effects of radiation eating on the sensing thermistor have been calculated for representative and extreme values of duct wall temperature, air temperature, and air flow at high altitudes. The aluminum coating and aluminum shields were assigned a reflectivity of 90 percent in the infrared. This is conservative, and the results of these calculations are shown in Appendix I, Table I, of the Monthly Progress Report, July 1961. Additional data is also available in the above listed Appendix pertaining to the development of this temperature sensor.

SECTION 4

PRELIMINARY TEST

4.1 PARACHUTE TEST

As was reported in the Monthly Progress Report of June 1961, the parachute requirements were determined to be as follows:

(a) Ribless guide-surface parachute.

(b) Silvered nylon material.

(c) Stability, 5 degrees.

(d) Diameter, approximately 3.75 feet

(e) Estimated sea level fall velocity, 45 ± 5 fps

(f) $C_D A$, approximately equal to 6.3 square feet

(g) Attachment cord at top of canopy, three leg bridle for attachment to sonde, and swivel at the bridle confluence

(h) Estimated time of fall for a 20 pound package, 15 minutes

A parachute drop test was conducted during the month of August 1961, with the use of a helicopter. Three successful drops were made from altitudes of 1000, 2000 and 3000 feet, at this point high velocity winds at altitudes above this level stopped the test.

The parachute guide line swivels were ordered and received with the parachutes. Because it is necessary to have an external battery to provide power to the sonde during the ascent portion of the flight, the possibility of the wires becoming fouled in this swivel is increased; therefore, the decision was made to eliminate the swivel and observe the sonde motion in both the ascent and descent portions of the dummy sonde flight test. With the swivel removed, attachment of the parachute by the shroud lines was made directly to the sonde shell with an imaginary confluence point 4 inches below the attachment point. The shroud lines were 3.2 feet long, and the parachute four feet in diameter with a package weight of 25 pounds.

During the ascent, no twisting or oscillations were observed, however, during the descent occasional oscillatory fishtailing of the sonde was noted, but no twisting or rotation was observed. Measurements of time-of-fall indicated a velocity of 55 feet per second when corrected to sea level conditions.

Following the dummy sonde drop test, considerations were given to disconnecting the external power cable from the sonde at the time of cut down. To accomplish this an input jack was mounted on the antenna end plate with a cable made of No. 16 wire with a plug attached to it, for insertion into the jack. The cable was then passed through the center of the parachute canopy to be connected to the power supply on the launch vehicle. For testing, this sonde-parachute configuration with power cable was suspended at a point high enough to allow the power cable to clear the entire parachute-sonde system before hitting the ground.

Several test drops were made, with each test contrived to cause a fouling of the power cable release. Various combinations of twisting shroud lines, and sonde pendulum motion could not prevent the power cable from pulling free. No indication of sticking, binding, or tearing of the chute was observed during these tests.

4.2 SONDE TRANSMITTER FLIGHT TESTS

During the week of June 19, 1961, flight tests were conducted at Hanscom Air Force Base to evaluate the performance of the two types of transmitters designed for the VST sonde package. Two transmitter packages, one a single-tube type and the other a two-tube type were included together with a complete transmitter spare of each type. Prior to shipment, all units were environmentally tested, and operated properly. Ground station equipment for this test consisted of an RS 201A receiver, an AMR-1 receiver, a preamplifier for these receivers, a ground plane antenna, and a corner reflector type antenna. In addition, a Polarad, Model R, microwave receiver was furnished by the AFCRL.

The balloon train used in the test consisted of a balloon, parachute, transmitter sonde package, and a modified AMT-4 Radiosonde. Modification of the AMT-4 consisted of removing the carbon humidity element and replacing it with a thermistor installed in the test sonde for internal temperature determination. A GMD-1 radio sonde receiver antenna was used in tracking the AMT-4 sonde included in the balloon train.

The sonde test package consisted of a battery pack, timer, keyer, modulator, and a 403 megacycle transmitter. The timer was set to turn the system on 30 minutes after launch. The keyer was used as a substitute for the commutator and alternately fed the transmitter with a value signal and an identification signal. The value signal was transmitted for 3 seconds, and the ID signal for 0.25 second. The value repetition frequency was 300 pps, and was chosen because it can be easily recorded by the AMR-1.

Two flight tests were made on June 21, 1961. The first balloon carrying the signal tube transmitter was launched at 10:35 a.m. At 11:00 a.m. the transmitter turned on, with the signal being received by all three receivers. The estimated distance was 20 miles and the altitude was 27 thousand feet. Immediately it was noted that the RS201 was not functioning properly, as it occasionally lost its output and the AFC would not track properly.

The AMR-1 began to have difficulties recording the value frequency at a distance of approximately 40 miles and an altitude of 80 thousand feet. The audio presentation was extremely garbled with ignition noise from cars and trucks in the general vicinity, and there was no output from the RS-201 receiver. The AMR-1 recording continued to become more noisy with an occasional complete loss of the signal as the flight progressed. The balloon broke at 92 thousand feet, with dropouts in the signal continuing as the sonde fell. Shortly thereafter the recording of the AMR-1 became mostly noise, with only the audio signal indicating that the transmitter was still working. The flight ended at 12:50 p.m.

During pre-flight checkout the transmitter frequency was set to 403 megacycles. When the transmitter initially turned on after launch, the frequency was 403.35 mc. As the flight progressed the frequency slowly drifted down to 402.5 mc just before loss of signal. The value frequency after initial turn-on was 318 pps; after an hour it was 320 pps, and at the end of the flight 325 pps. Because of the high noise content in the signal and the time duration of the pulse, the ID signal could only be observed on the oscilloscope. It was noted that there was little or no drift to this frequency.

The second flight was made in the afternoon using the two-tube transmitter. Results of this flight were almost identical to the first, with the signal continuing at an equally high noise content. Initial turn-on frequency for this transmitter was 404.8 mc, and it drifted

to a final value of 404.2 mc. The value frequency was initially 330 pps and finally 331 pps.

As a result of these two tests, the following conclusions can be drawn:

(1) The frequency stability of the transmitter, the value pulse and the ID pulse are satisfactory.

(2) The signal to noise ratio was unsatisfactory.

(3) From Item (2) it can be concluded that either lack of transmitter power or poor performance of the ground equipment was the ma_ı source of trouble. Since the power output of the transmitters is approximately 25 watts, checks on the ground equipment were indicated.

(4) Since there was no discernible performance difference between transmitters, and since the construction of the two-tube type is more costly, the single tube transmitter was selected for future use. Antenna loading for which the two-tube type was designed was not prevalent during these flight tests.

Investigations into the poor signal reception were started immediately after the flight tests. The lead-in cable from the antenna was a coax cable, type RG-58A/U, approximately 100 feet long. Tests showed this cable to have a 14.2 db power loss at 400 mc and was determined to be the major cause of poor signal reception. The antenna cable loss for the actual VST ground station was measured at 0.6 db. Tests were conducted on the receivers to check their alignment and sensitivity, and the AMR-1 was found to be slightly misaligned, with its sensitivity being increased by 10 db with proper alignment. These tests were continued on the RS-201 and the preamplifier, which resulted in improved operational characteristics.

Background noise such as was experi^nced during the flight tests with the ground plane antenna indicate that a directional type antenna might be more favorable. Such an antenna would have a higher gain, and if visual contact with such units as the GMD-1 tracking antenna are possible, then proper orientation of such an antenna could be done manually.

As was reported in the Monthly Progress Report of October 1961, a second transmitter test was conducted. The sonde package under test consisted of a transmitter junction box, commutator, and battery pack assembled in a final configuration sonde package phenolic tube. Instead of a balloon, a helicopter was used as the transporting vehicle with the sonde suspended 15 feet below the craft.

The commutator had a known set of values on each channel to be used for correlation of data at the receiving station.

The first 10-mile leg of the test was conducted at an altitude of 1500 to 1700 feet, with signal reception strong and clear. On the second leg, shortly after picking up the signal upon take-off, a fading of the signal was noticed. This became more pronounced as the distance became greater, and at one point the signal was completely lost for a period of one minute. Just before landing at the 25 mile point, the signal strength increased and reception was good again. The altitude during this second leg was 2800 to 3000 feet. Instructions were given the pilot to go to 4000 feet and hover for 3 minutes and then to continue with the flight. At the 4000 foot altitude the reception was excellent. However, during the latter portion of this run, transmission again became erratic. At the 40-mile point the altitude was 5000 feet; the pilot was then instructed to go to 6000 feet and hover for five minutes and then return to the starting point at an average altitude 1000 feet above that on the outgoing trip. As a result, the reception on the return trip was excellent all the way.

After the termination of the flight test it was learned that the maximum distance from the receiving station was 55 miles, which was approximately 15 miles further than that attained during the first flight test. The reception at this distance was excellent, indicating that there was plenty of power available from the transmitter.

Apparently, changes in the terrain were the principal causes of fade-out encountered in the outgoing portion of the trip. This was substantiated by the fact that the increase in altitude on the return trip alleviated the fade-out problem. It was later learned that a series of hills with an elevation of about 600 feet lie about 15 to 20 miles from the receiving station point and the line of flight.

The accuracy of the signal transmitted appeared excellent. The high range linearity channel was used as a check point, since it and the low-range linearity channel would be used in actual flights to provide corrections caused by deviations in transmission. On these channels, the count changed by a total of 2 parts in 1700 during the flight.

SECTION 5

VST GROUND STATION

5.1 GENERAL

The purpose of the ground station equipment is to provide a reliable, accurate, and automatic means of receiving, decoding, and recording the transmitted meteorological data from the sonde package during the in-flight evaluations of the various sensor techniques. The ground station equipment is installed in the GFE trailer van as shown in Figure 8, and consists, for the most part, of airborne equipment originally developed for the Air Force AN/AMQ-15 Meteorological Reconnaissance System.

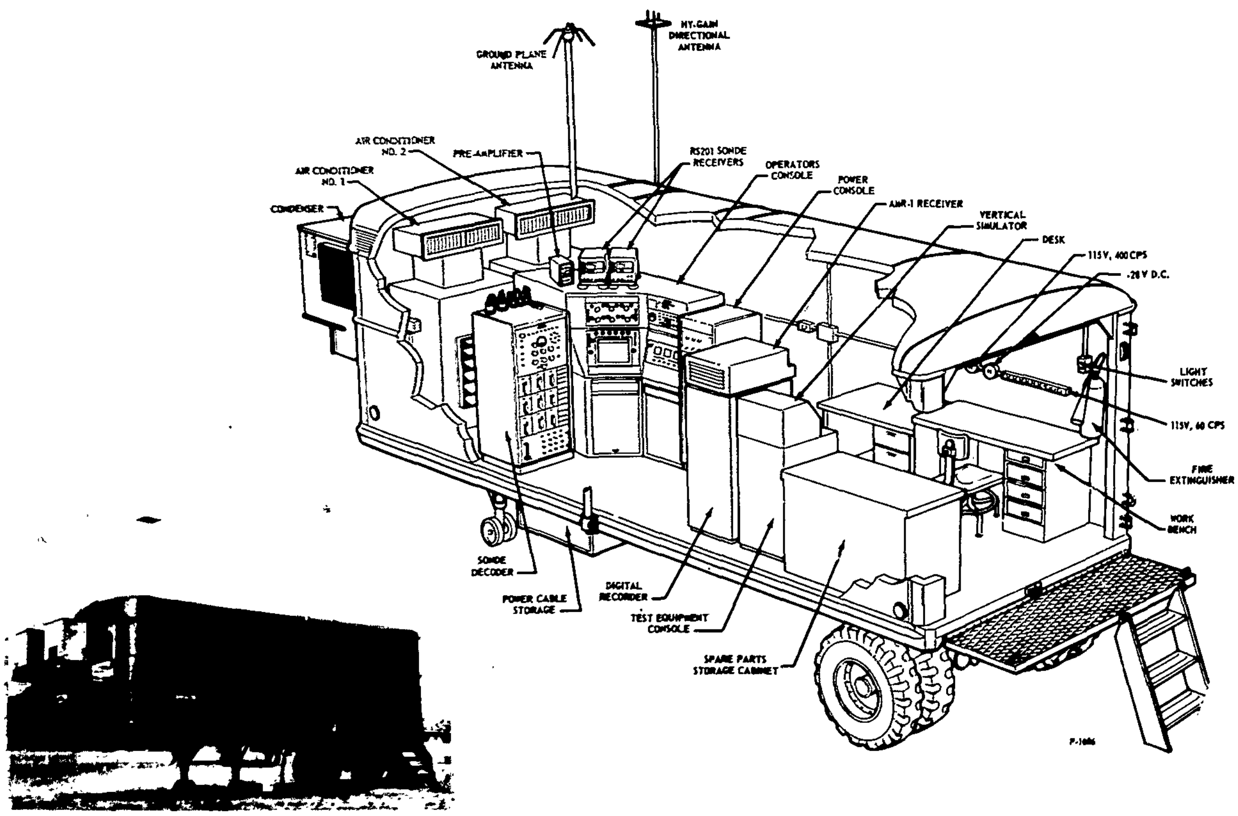

Figure 8 - VST Ground Station

The VST Ground Station Equipment performs the following functions:

(a) Records the received meteorological data on magnetic tape in a digital format compatible with the translator - computer equipment of the ASD Computer Facility.

(b) Records the sonde transmitted data on magnetic tape as it is received. These data are recorded as a "backup" measure in case of malfunctions in recording operation (a).

(c) Records the meteorological data in digital form on printer tape. These data are presented in two columns: A time base printed in seconds, and time intervals corresponding to the value information transmitted.

(d) Provides a visual display of selected sensor signals in analog form on a graphic recorder as amplitude versus real-time. This function is intended to provide a means of monitoring the received sensor data by the ground station operating crew.

In addition to the receiving portions of the ground station, such as antennae, pre-amplifier, and receivers, the major ground equipment units located in the mobile van are: the Sonde Decoder which accepts the pulse modulated signals from a RS201 Sonde Receiver and decodes and converts this information into digital form; the Operator's Console which includes (a) the Raw Data Recorder, which records the digital information in binary form on magnetic tape; (b) the Sonde Receiver Output Data Recorder, which records the meteorological data received by the Sonde Receivers directly on magnetic tape; and (c) the Brush Recorder, which provides an amplitude versus real-time graphic display of selected analog signals; the Digital Recorder, which accepts sonde signals from the AMR-1 Receiver and records the value intelligence on a time interval basis; the Power Console; and Test Equipment used for pre-flight calibration and consisting of a Vertical Simulator, oscilloscope, Microwave Power Meter, and a Wide-range Oscillator.

A description of the operating characteristics of the ground station is presented in the following paragraphs together with a summary of equipment development.

5.2 BACKGROUND

The Vertical Sensor Techniques Proposal Number 668, submitted April 29, 1960 states that the equipments mentioned herewith will be used in the ground station system.

The first item is the AN/AMQ-15 sonde decoder, which due to its capabilities and restrictions dictates both the transmitted data format and methods of recovering information. The units to be used for data storage consist of units of the AN/AMQ-15 raw data recording system. The AN/AMQ-15 pre-amplifiers and receivers will be used as receptors, the process data recorder is to be modified and used as a storage unit for transmitted data. The AN/AMQ-15 Brush Recording equipment is to be used for a sensor data display for constant monitoring during flight. The AN/AMQ-15 digital clock is to be used in the same capacity as on the AN/AMQ-15 program.

The purpose of the ground station is to provide a reliable, accurate, and automatic means of receiving and recording transmitted data from the sonde package. This equipment performs the following functions:

(a) Records on magnetic tape in digital form, the data taken from the Sonde Decoder and Raw Data Recording Equipment.

(b) Records on a second magnetic tape data taken directly from the receivers. This is recorded only for backup information in case of a malfunction of the equipment in "a" above.

5.3 SIGNAL FLOW

A description of the operating characteristics of the ground station is included in the following paragraphs.

As the block diagram (Figure 9) indicates, the signal, after being picked up by the antenna, is fed into a pre-amplifier which has a 5 micro-volt sensitivity. The output of the pre-amplifier is sent to two receivers. One receiver is in the stand-by condition, while the other

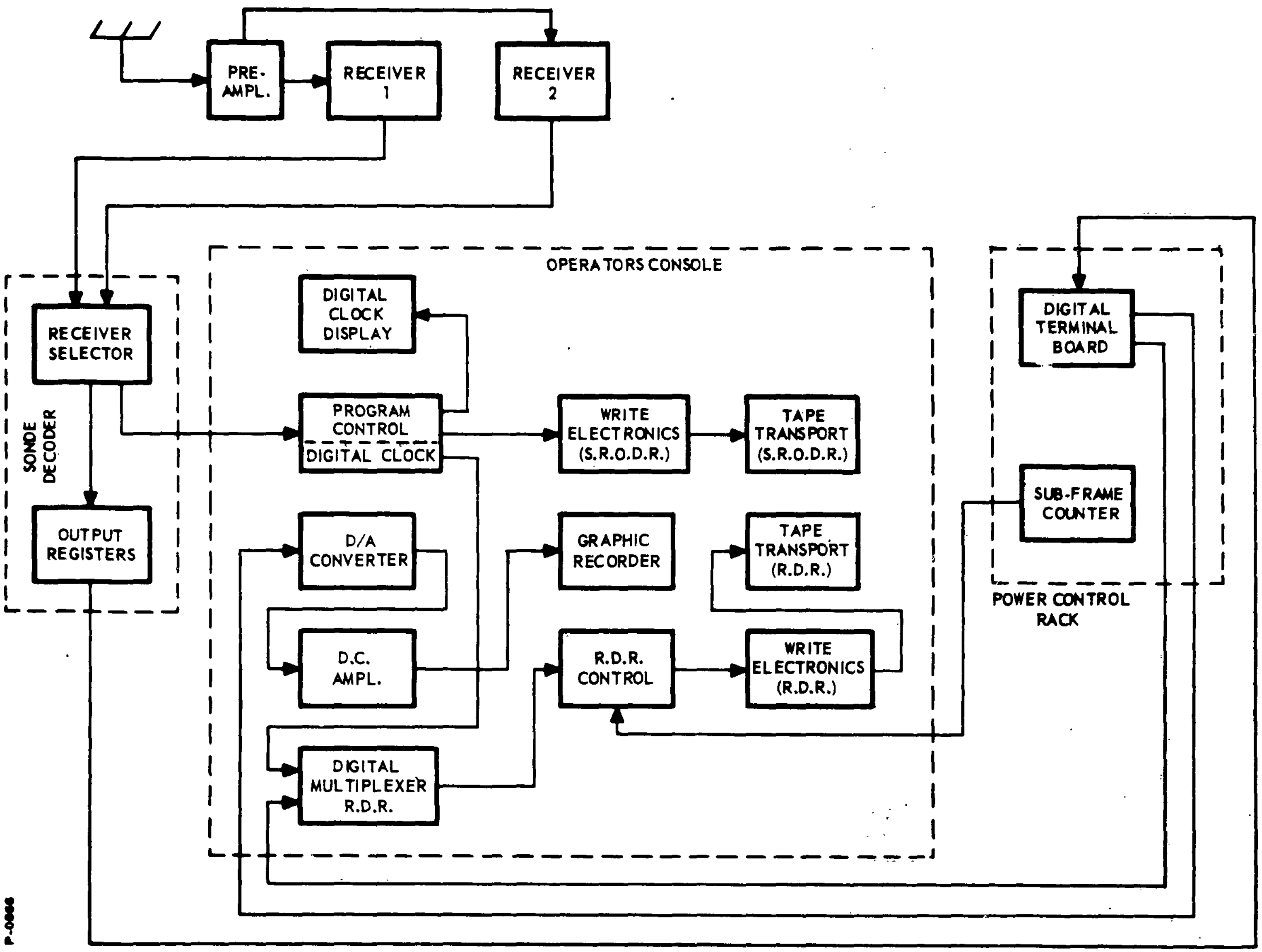

Figure 9 - VST Ground Station Signal Flow

sends its output to the sonde decoder. Both outputs are controlled by the operator from the sonde decoder monitor panel. The receivers are set to a center frequency of 403.0 megacycles and each has a total bandwidth of 1.5 megacycles. The output signal from the receiver, is a 1 to 3 microsecond pulse of -9 volts amplitude, and is fed to the sonde decoder receiver selector relay. From the relay the signal is divided; one signal is connected to the program control panel. Here the receiver output signal is frequency divided by two in order to stay within the frequency response limits of the sonde receiver output data recorder (SRODR). The output of the program control panel is fed to this recorder through switching circuits on the operation monitor panel. The other signal from the selector relay enters the sonde decoder logic circuitry. Two ranges of frequency are used in this signal. One is an identifier pulse train consisting of eight individual codes with a pulse interval range of 40 microseconds to 635 microseconds and the other a value pulse train with a pulse interval range of 640 microseconds to 10.235 milliseconds. As the identifier pulse train enters the logic circuitry the first pulse starts the forward counter; the second pulse transfers the count of the forward counter to the backward counter and the backward counter starts counting toward zero. If the backward counter reaches a zero count or a near zero count by the time the third pulse is received, and the frequency of the in-coming signal is within the limits of one of the eight identifier codes, the decoder stops counting and opens a logic gate corresponding to the identifier received and is ready to accept a value pulse train. This pulse train is counted in the same manner as the identifier pulse train and is stored in the register previously identified. In the manner just described a serial pulse train is converted to eight parallel 10-bit binary outputs.

These outputs are connected to the digital terminal board for distribution and are then sent to the Raw Date Recorder (RDR) and to a passive digital-to-analog converter. The latter unit is used in conjunction with the Brush graphic recorder, which provides a visual display of various sensor signals and is intended as an on-the-spot check of sensor data. In addition to the eight output signals going to the RDR, the digital clock signal is also connected to the RDR. As shown in the block diagram the RDR consists of the digital multiplexer, control unit, write electronics, and tape transport. Thus, the incoming information is multiplexed, fed to the control unit and then put on tape.

Figure 10 shows the tape format being used. Here one frame consists of 66 words sub-divided into 3 sub-frames of 22 words each. The first sub-frame contains digital information--that is, information which is in digital form at its origin. The second and third sub-frames contain analog information. The first two words are followed by 20 words of digital or analog information. However, at the present time there is no analog information available and the second and third sub-frames will contain all zeros. As far as the digital sub-frame is concerned, only 11 words of the 20 are used, 8 from the sonde decoder and 3 from the digital clock. The unused words in this sub-frame will also contain zeros. The above format containing 66 words is necessary for compatibility with the tape translator at ASD.

5.4 REAL TIME CODING

The clock information, which are words 3, 4, and 5 is in binary - coded - decimal form, but goes on tape as straight binary. The real time clock information has been wired into the binary positions in the following manner:

Binary Position	Seconds	Minutes	Hours
2^0	2^0 Units	2^0 Units	2^0 Units
2^1	2^1 Units	2^1 Units	2^1 Units
2^2	2^2 Units	2^2 Units	2^2 Units
2^3	2^3 Units	2^3 Units	2^3 Units
2^4			
2^5	2^0 Tens	2^0 Tens	2^0 Tens
2^6	2^1 Tens	2^1 Tens	2^1 Tens
2^7	2^2 Tens	2^2 Tens	
2^8			
2^9			

5.5 GFE AND GBE EVALUATION

As soon as the GFE and GBE was received from Wright Air Development Division, checkout was begun to determine the condition

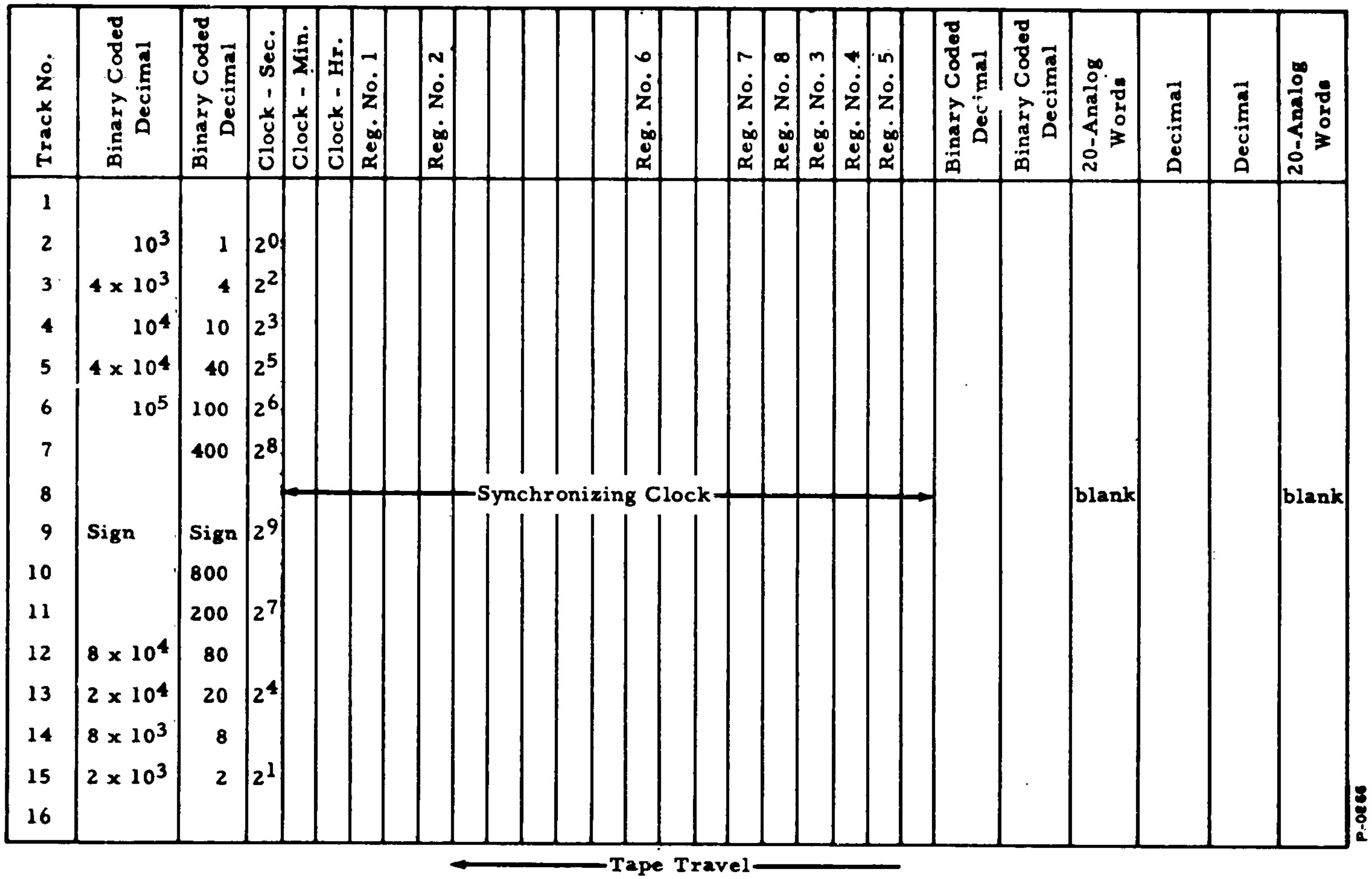

Figure 10 - One Recording Frame-RDR Tape Format

of this equipment. In the following paragraphs an attempt will be made to summarize the repair and modifications required to assemble the final configuration of the VST ground station.

The first item that was checked was the 403.0 megacycle radio sonde signal generator; it was found that the output tube was weak and some of the wiring had been disconnected or broken. After determining the cost of repair it was decided that if and when a 403.0 megacycle signal was required a Hewlett Packard 608 Signal generator would be used. The RM16 Tektronic oscilloscope was received without a power cord or test probe; these items had to be purchased before using the oscilloscope. A power supply, Polytechnics Model 807, was found to have a bad regulator tube and the voltage control potentiometer was defective and was replaced. In order to continue checking out the units that were to be placed into the ground station operation, connectors had to be purchased and cables made for approximately 70 percent of the equipment.

After the interconnecting cables had been fabricated, the first unit to be checked was the program control chassis. When main power was applied to the power supplies for this chassis, both the positive and negative 12 volts were found to be inoperative. One supply was found to have a broken lead on a power transformer and the regulation circuit of the other unit was not functioning. To correct this, one diode and three transistors were replaced. Further checking of the program control chassis disclosed an inoperative flip-flop circuit. Before checking could begin, the program control chassis that generates the real-time-display required the procurement of 6 digital light modules to display hours, minutes, and seconds. Four of the modules required for display were removed from the AN/AMQ-15 Program Control Panel and 2 units were purchased. These units were wired and connected to the program control chassis in conjunction with the proper reset switches. This unit was run both on its internal frequency generating device and the 60 cycle power source for a period of time to determine if any additional malfunctions would occur. All circuits on this chassis that were used for the intervalometer circuits on the AN/AMQ-15 program were disabled to prevent any circuit malfunctions not directly related to the digital clock circuit.

The portion of the Program Control Chassis that was used for the reference data panel was modified and utilized to display real time in digital form on the raw data recorder tape.

5.5.1 Sonde Receiver Output Data Recorder

The primary purpose of the sonde receiver output data recorder, Figure 11, (SRODR) is to provide a back-up recording facility for the ground station data link, so that in the event of decoder or raw data recorder failure during a flight test, the data would not be lost. To accomplish this the SRODR must record the intelligence picked up by the Sonde Receiver, as well as real time; and it must also be capable of playing back the information in its original form.

Figure 11 - Components of the Sonde Receiver Output Data Recorder

An Ampex Model 800B tape transport and its associated electronics are the basic building blocks for the scheme. This recorder, which has a 16 channel recording capacity and utilizes a non-return-to-zero mode of recording, was residual inventory from the AN/AMQ-15 airborne equipment.

To record the high pulse repetition frequency from the Sonde Receiver and still stay within the frequency response limitations of the recorder, it was necessary to select alternate pulses and record them on one channel, while recording the intervening pulses on a second channel at a recording rate of 15 inches per second. Prior to being recorded, the pulse repetition frequency is divided by two in the write electronics. Each channel of the write electronics acts as a bistable circuit, in that two input pulses are required to return the write electronics output to its original state.

The separation of alternate pulses was accomplished by feeding the Sonde Receiver output signal to a shaping amplifier and thence to a flip-flop circuit. The two outputs of the flip-flop were fed to separate channels of the write electronics and then recorded. The shaping amplifier and flip-flop circuits are mounted in the Programmer Control Chassis which also houses the Digital Clock. To record a real time clock signal, the 60 cps point in the frequency division scheme of the Digital Clock was fed to the write electronics, and was put on a third tape channel as 30 cps.

To recover the recorded information, a high gain pre-amplifier was used in conjunction with the record head which in this mode was used as a playback head on each channel. Each pre-amplifier provides two outputs, 180 degrees out of phase, which drive shaping amplifiers that in turn trigger one-shot multivibrators. The multivibrator outputs are summed, and fed to an emitter follower circuit for impedance matching with the sonde decoder.. The recovered clock signal, after being amplified, is fed into the playback 30 cps input point of the Digital Clock.

5.5.2 Raw Data Recorder

The three modifications which were required in the raw data recorder, are the modification of the recording format from one 60-word frame to three 22 word sub-frames, and the changing of the recording rates from 8, 1, and 1/2 frames per second to 5 and 2-1/2 frames per second. The provisions for recording radar data in the raw data recorder were also eliminated.

In order to modify the raw data recorder, an extra chassis (designated the sub-frame counter chassis) was required. The essential functions of the sub-frame chassis are those of counting the number of sub-frames and providing control signals in conjunction with the control chassis to activate the remainder of the recording logic.

Counting the number of sub-frames is accomplished by updating a binary-coded-decimal counter for each successive sub-frame. The output of the sub-frame counter consists of a 21-bit binary-coded-decimal number. This number is recorded within the first two words of each sub-frame. The remainder of each sub-frame is composed of 20 ten-bit words. The first sub-frame contains digital information, the second and third sub-frames contain analog information. The control

signals are generated within the sub-frame chassis by means of two two-stage counters and the outputs of these counters are gated in such a way that they control the recording format. The complete order of recording within a sub-frame is shown in Figure 10.

The major modification in the control chassis in conjunction with the recording format was that of modifying ten two-input AND gates and five two-input OR gates to accept three inputs. Consideration was given to replacing these gates with commercially available three-input gates. However, it was determined that it would be more economical to modify the existing gates. Other modifications within the control chassis consisted of removal of logic circuits concerned with radar, changing the basic word-clock rate, and rearranging other control signals to accommodate the new tape format.

The raw data recorder panel was modified to provide a push button for resetting the sub-frame counter to zero.

5.5.3 Digital Terminal Board

After receiving the digital terminal board, the first step taken was the generation of a pin function cable-to-cable continuity check and a terminal pin function diagram. This was necessary because there was no wiring diagram available on this unit and further work could not continue until the internal wiring layout was known. The connectors that were once used to feed information to the RWD-300 computer on the AN/AMQ-15 program are utilized now as inputs to a passive digital-to-analog converter that has been developed, and can provide an output from the sonde decoder for display on the Brush Recorder.

5.5.4 Sonde Decoder Monitor Panel

The Sonde Decoder Monitor panel was modified to add a transfer switch and four signal lamps. Two of these lamps indicate which of the receivers is being used with the decoder, while the remaining two indicate the presence of an output from the receiver. The latter function is carried out by integrating the audio output of each receiver (a 500 micro-second pulse) and using it to feed a lamp drive amplifier. A lighted lamp indicates that a receiver output signal is present.

5.5.5 Sonde Decoder

Two modifications in the Sonde Decoder were made to facilitate a means for supplying an input to the SRODR tape recorder

with a minimum amount of switching. This was accomplished by providing an external control switch on the decoder monitor panel to control the transfer relay in the Sonde decoder. The simulator input connector on the test panel of the decoder was interchanged with the "Input Test" jacks to provide an output for the SRODR no matter what the position of the transfer relay, or what receiver output was being decoded.

5.5.5.1 Decoder Output Content

The commutating scheme on the AN/AMQ-15 was a simple identification pulse followed by a value for 8 different parameters. However, the commutating method used now has 24 channels for sampling, with only 8 output registers in the decoder. This means that each register will handle 3 of the commutator channels. For instance, register 1 will handle value channels 1a, 1b, 1c of the commutator while register 2 handles 2a, 2b, 2c, etc. The actual scan sequence of the commutator is to 1a, 2a, 1b, 2b, 1c, 2c, 3a, 4a, - - - - 7b, 8b, 7c, 8c, 1a, 2a.

5.6 SONDE RECEIVERS

Three RS201A Radio Sonde Receivers and one AMR-1 Radio Sonde Receiver were received with the ground station equipment.

Of the three RS201A Radio Sonde Receivers one had a power transformer that was inoperative, and was not repaired; the other two required different crystals to properly align them on a center frequency of 403 megacycles. The AMR-1 Radio Sonde Receivers operation on the 403 megacycle signal was good; however, its output was not compatible with the associated ground equipment. As this receiver displayed better sensitivity than the RS201A Receiver using input signal preamplification, the video chassis was used from the inoperative RS201A Receiver as an output pulse generating circuit.

5.7 OPERATIONS MONITOR PANEL

The Operations Monitor Panel was constructed to house the digital clock display units, the clock reset switches, the clock source control switch, and the graphic recorder selector switch, and also the tape recorder channel selector switch. The graphic recorder selector switch permits displaying either registers 5 and 6, or registers 7 and 8 of the decoder on pens 5 and 6 of the Brush recorder. The tape recorder channel selector switch controls the stacking of information on the SRODR recorder for maximum usage of tape.

5.8 ANTENNA EVALUATION

As a result of the flight test conducted at Hanscom Air Force Base during June 1961, receiving antennae were investigated. The antenna used in the test was an omnidirectional quarter wave dipole, however, it has a severe signal loss directly over head. This antenna was chosen originally because of difficulties in trying to orient a directional type antenna on the ground station trailer.

To obtain improvement in signal reception, a directional ground plane antenna (Figure 12) was constructed with movable directors and reflectors. Tests were conducted in an antenna test chamber to determine optimum spacing of the inactive elements. The final configuration has a director spaced at 0.1 wave length and a reflector located at 0.2 wave length away from the active element. Test patterns (Figures 13 and 14) were run which indicate the antenna pattern to be fairly uniform from 0 to 60 degrees of elevation angle, and at the same time, the vertical sensitivity remained good. The horizontal pattern was uniform over approximately 120 degrees.

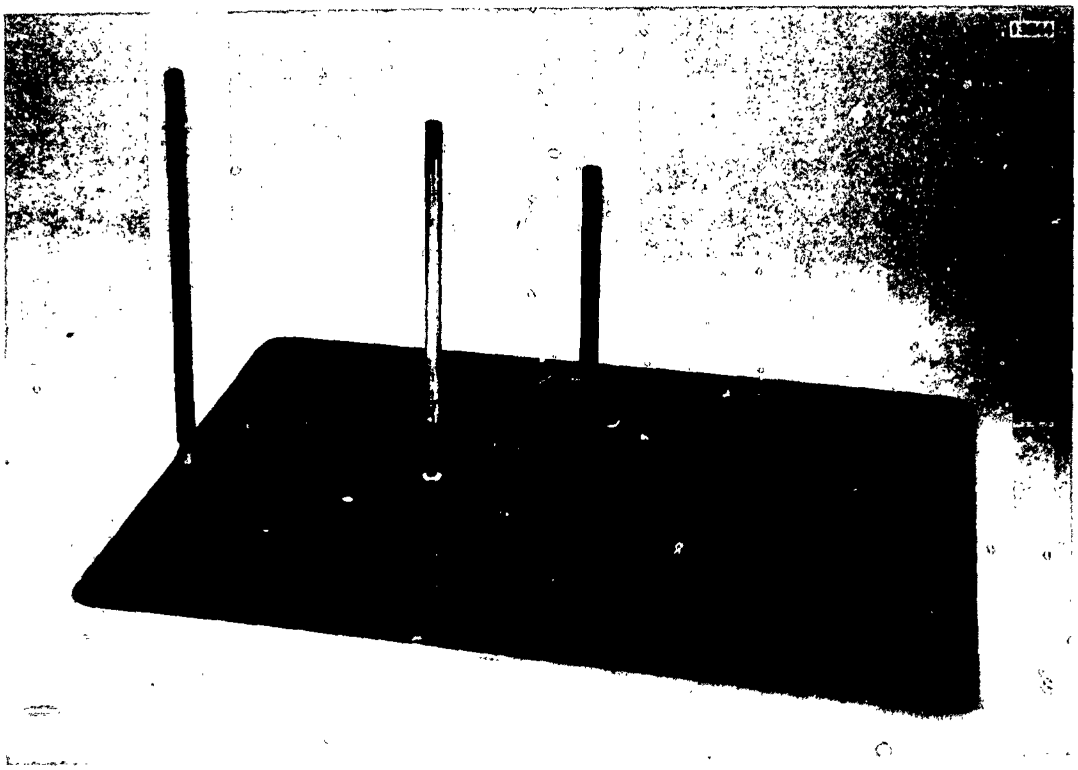

Figure 12 - Experimental Sonde Directional Receiving Antenna

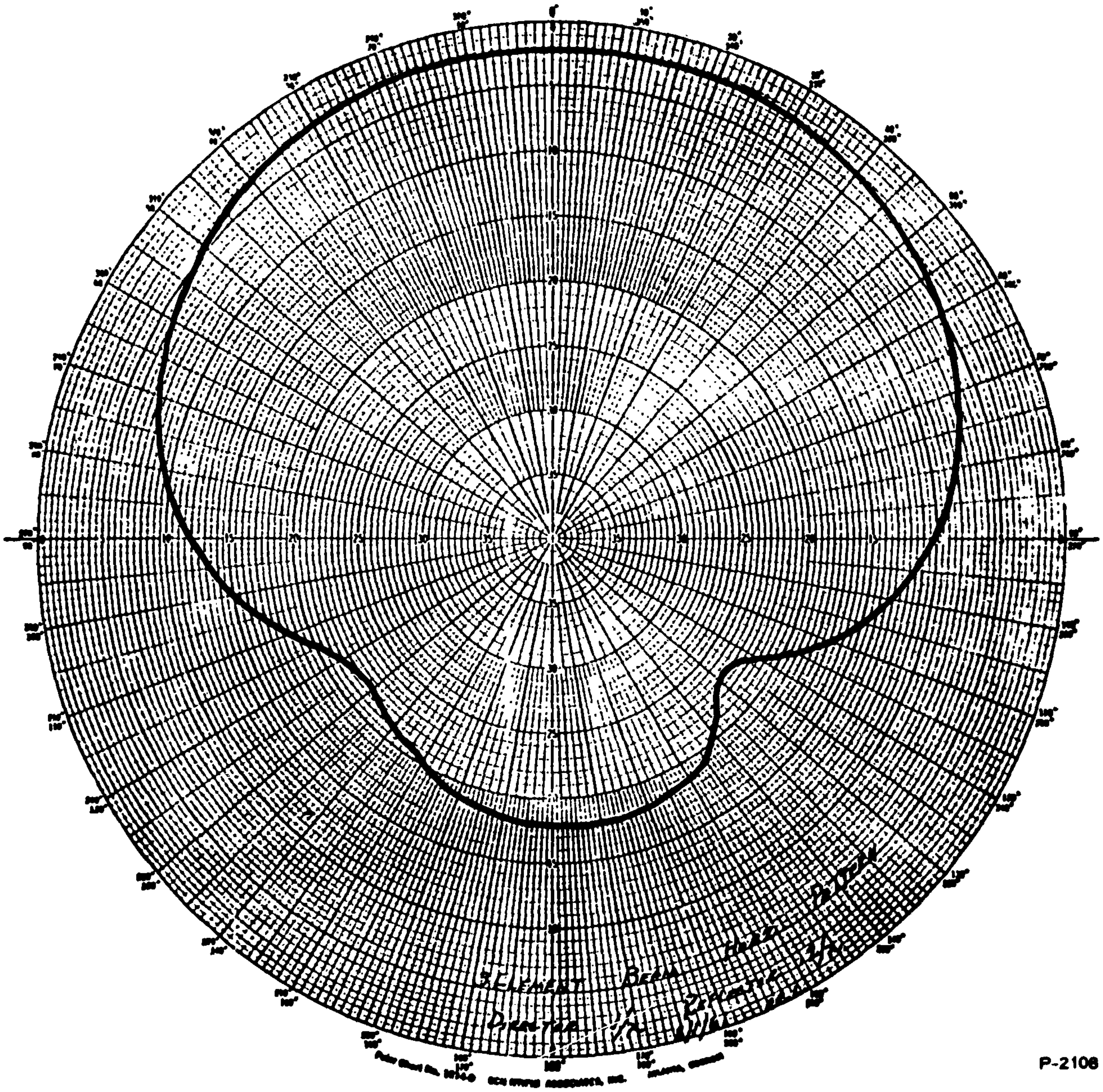

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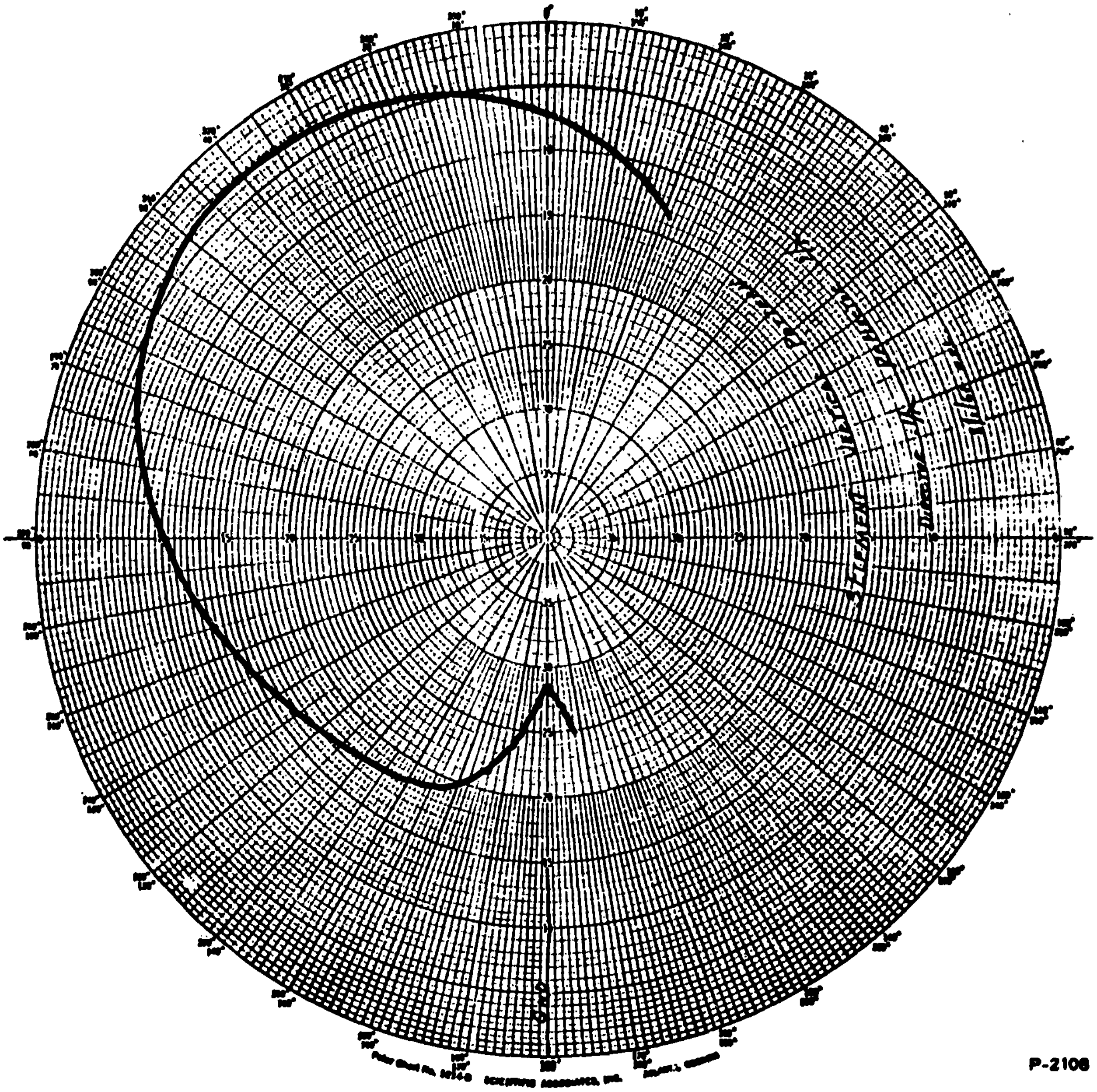
Figure 13 - Three Element Beam, Horizontal Pattern



P-2108

Figure 14 - Three Element Beam, Vertical Pattern

This antenna has a 6.5 db gain in sensitivity over the quarter wave dipole. The front-to-back ratio of this antenna is 15 db, which is another improvement over the dipole antenna. In operation, this antenna can be manually oriented to the direction of flight the sonde takes at launch, or if the GMD-1 is near by, visual correspondence with the GMD-1 antenna can be made.

5.9 TRANSMISSION TEST

After the equipment was mounted in the GFE trailer a final test insured that all phases of the ground station were functioning properly. A battery-operated sonde transmitter package was flown with a programed commutator output. With the use of a helicopter, tests were made at varying distances and altitudes to determine if there were any receptability problems. The maximum distance tested was approximately 55 miles at an altitude of 6000 feet. At this range it was determined that the directional antenna was far better on the reception of the signal. This was determined by connecting one receiver to the dipole antenna and the other to the directional antenna. The receiver on the dipole dropped out completely at about 40 miles while the other receiver never lost contact.

The register content of the decoder was checked and compared with the known input and found to be accurate. The flight information was also checked on the Brush recorder and found to be correct. A recording was made by the SRODR of portions of the flight and played back with very good accuracy.

As a final phase in checking the raw data recording format, a method of presenting changing data was discussed with WADD, Air Systems Division personnel. With their recommendations a programed test tape was run as a means of checking the output of the translator with this type of input.

As an aid in operating, maintenance, and trouble shooting procedures a manual was written entitled; "Operation Manual, Telemetry Ground Station for Meteorological Data Handling, Mobile," published as a Bendix Research Division Report Number 1949.

SECTION 6

FLIGHT TEST

The flight test for the Vertical Sensor Techniques program was conducted in Chico, California during the month of February 1962. The success achieved in this portion of the program was made possible through the cooperation received from the balloon launch team of Hanscom Air Force Base and Mr. Ralph Cowie of the Air Force Cambridge Research Laboratories.

After the termination of the flight test, the data gathered from each sonde flight required reduction from a 10-bit binary word system on magnetic tape to a usable form. This was accomplished through the cooperation and assistance received from the personnel of the computer facilities, Aeronautical Systems Division, Wright-Patterson Air Force Base, and especially Mr. John Hicks and Mr. Donald Foster of that installation. The processed or translated data was received in the form of a binary coded decimal system, which could then be further reduced to the binary number output of the Sonde Decoder. In order to relate this binary number to the voltage output of the individual sensor the constants of each sensor output circuit were then applied. The application of an error correction factor at this point made it possible to associate this voltage to temperature, pressure, or whatever the parameter was.

6.1 FIELD FLIGHT TEST

In the following paragraphs an attempt is made to familiarize the reader with the function of each sonde flight. The points that are monitored on each flight will be listed under each flight heading with the exception of the functions monitored on every flight. Those items are the Lo-Linearity and Hi-Linearity points that are required for the determination of the error correction factors, and the B(-) and B(+) points used to monitor the battery voltages.

6.1.1 Flight No. 1

The first balloon was launched at 8:15 a.m., February 17, 1962, with an approximate ascent rate of 1000 feet per minute to an

altitude of 90,000 feet. The sonde was cut from the balloon vehicle at 10:35 a.m. at an altitude of 92,471 feet with a slant range of 50 miles from the receiving station. The sensors used on this first flight are listed below:

1. Hypsometer No. 1
2. Hypsometer Heat Sink No. 1
3. Hypsometer No. 2
4. Hypsometer Heat Sink No. 2
5. Sonde Frame Temperature
6. Temperature Sensor
7. Baro-Activated Pressure Sensor
8. Carbon Humidity Element

This sonde contained two hypsometers as pressure measuring devices. The output or indicated pressure of both units were quite compatible in that both curves follow (Figure 15) one on top of the other. The baro-activated pressure sensor that was included in this sonde as a method of correlating pressure data apparently froze in one position, as the output remained the same throughout the flight.

The temperature sensor thermistor mounted in the index of refraction sensor sample tube inlet indicated an output (Figure 16) which seems correct with reference to the I.C.A.O. atmosphere charts.

After the pressure-temperature data had been reduced a comparison chart was constructed (Figure 17) with the AMT-4 data received from the balloon in the ascent portion of the flight. It was known however, that the particular mounting place selected for the AMT-4 did not lend itself to accurate temperature measurement due to the reflective surfaces of the ballast canisters on the launch vehicle. The curves for both data sources show a definite agreement at the lower altitudes with the main difference at the higher altitudes being temperature as noted above.

The associated readouts referenced to the hypsometer were also graphed. The sonde frame temperature data (Figure 18) indicated that the temperature variation was from a +5 °C at the beginning of the flight to a -1.25 °C after nine and a half minutes had

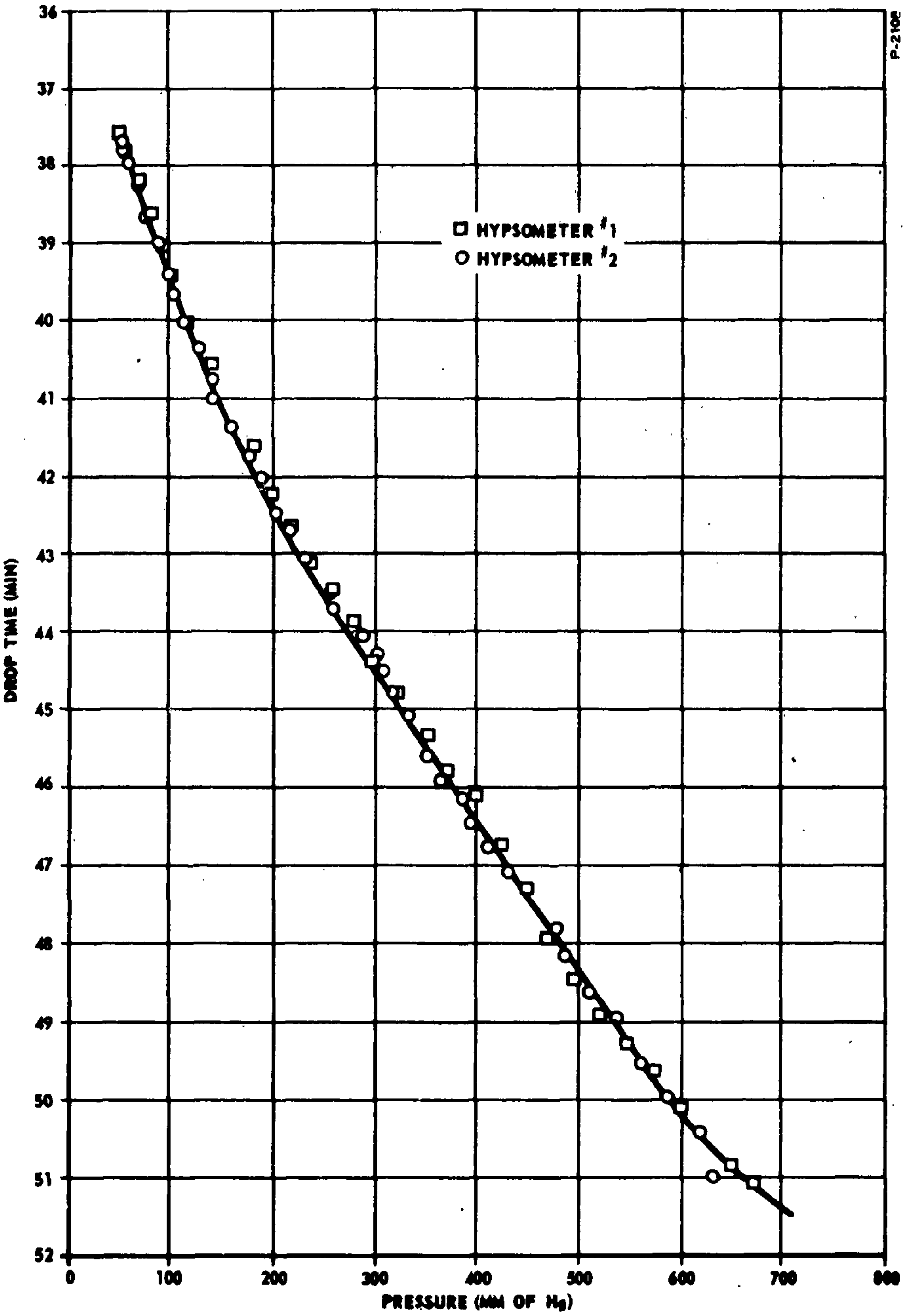


Figure 15 - Hypsometer Output, Flight No. 1

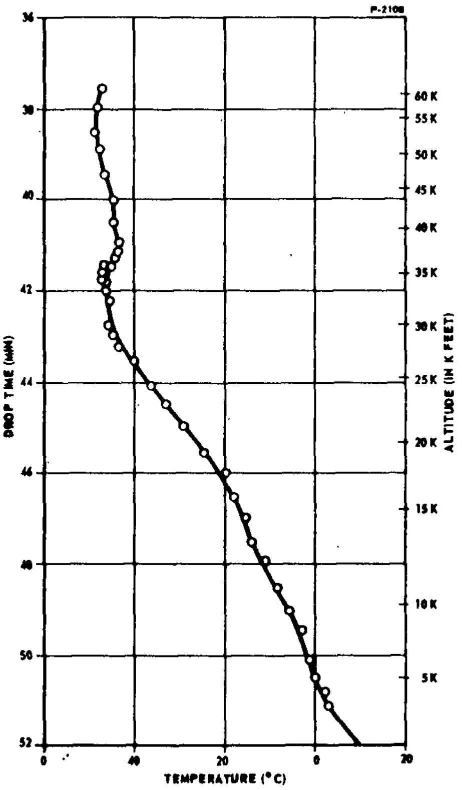


Figure 16 - Temperature, Flight No. 1

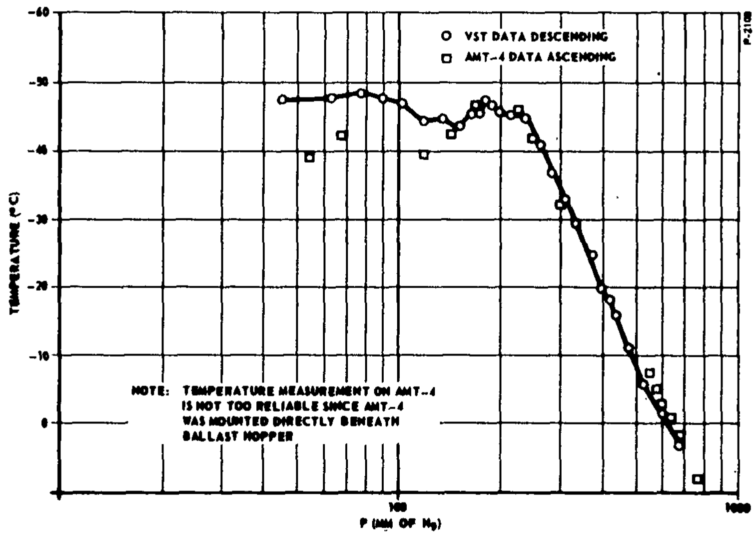


Figure 17 - Pressure-Temperature Comparison, Flight No. 1

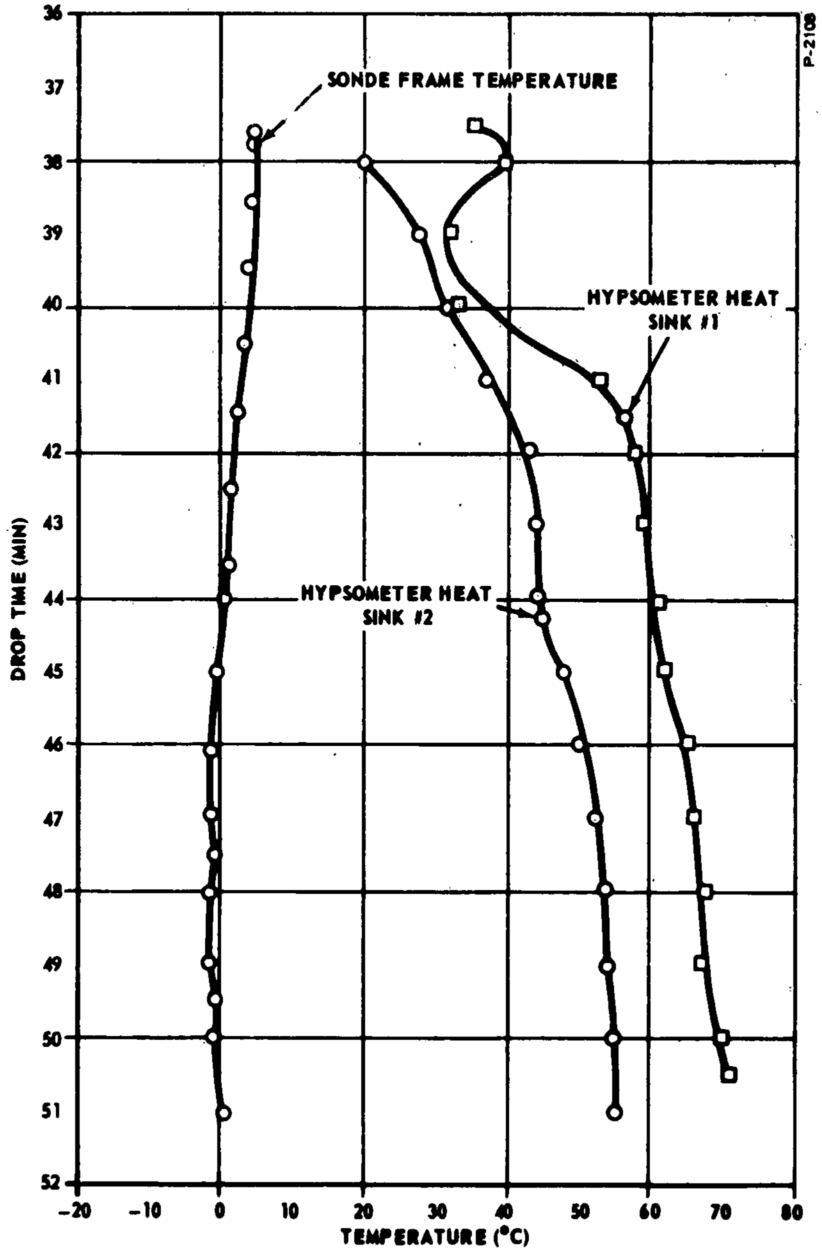


Figure 18 - Hypsometer Data, Flight No. 1

elapsed. The final temperature indicated a 0 °C reading at the termination of the flight. The two heat sink temperature sensors, one for each hypsometer, indicate an offset between the two of about 15 °C. The heat sink temperature referenced to No. 1 hypsometer shows a steady increase in temperature from a +20 °C to a +55 °C. However, the heat sink temperature referenced to No. 2 hypsometer starts off at a +35 °C, with an erratic display after three minutes of flight and remaining for the rest of the flight. This erratic display of heat sink temperature could be due to a faulty thermistor.

The remaining sensor on board this flight was the carbon humidity element. After the data was reduced on this sensor there appeared to be very little change. It is considered very possible that during the ascent portion of the flight the element became saturated and did not recover or assumed an offset greater than the levels of moisture encountered on its descent.

The time in which the first data was recorded and the announced cutdown took place differs by about 2 minutes. It is doubtful that the time difference was that great; however, the recorded altitude at cutdown was approximately 92,000 feet and approximately 64,000 feet at the first data recording.

6.1.2 Flight No. 2

The balloon and instrument package were launched at 9:34 a.m., February 19, 1962. The cutdown time was scheduled for 11:36, however, approximately 30 seconds prior to this the balloon ruptured at 91,013 feet and the sonde package was released immediately.

The following is a list of sensor outputs for this sonde flight:

1. Hypsometer
2. Hypsometer Heat Sink
3. Sonde Frame Temperature
4. Temperature Sensor
5. Ozone Sensor
6. Ozone Sensor Temperature
7. Ozone Electronic Card Temperature

8. Carbon Humidity Element

9. Baro-Activated Pressure Sensor

10. Velocity Sensor

As in the first flight, the first data reduced was for the hypsometer and temperature sensor. Both of these curves (Figure 19) were shaped the same as those seen previously, but were displaced slightly. A pressure-temperature comparison was also made with the data reduced from the sonde and that from the AMT-4. The shape of both curves are alike (Figure 20); however, at the upper end of the flight there is a separation again believed to be due to temperature difference between the two methods of sampling with respect to their surroundings.

The sonde frame temperature data taken with reference to the hypsometer indicated a nearly constant temperature of +7 °C. The hypsometer heat sink temperature, however, reacted the same as seen in Flight No. 1 increasing from +10 °C to a +70 °C.

The carbon humidity element data was reduced and plotted against the relative humidity data gathered from the AMT-4. Both sets of data plotted appeared to be very erratic and were considered to be of no value.

The first ozone sensor was also flown in this particular sonde. The data recorded at the beginning of the sampling period indicated saturation of the film. There is a reasonable possibility that a high concentration of ozone was present at the start of the flight. Additional points were monitored in the ozone sensor such as the electronic card temperature (Figure 21) which maintained a temperature of a +23 °C throughout the flight. The temperature of the sensor chamber itself was steady at a very low temperature indicating possible heater blanket failure. However, this sonde was recovered after the flight and the thermistor used for the ozone sensor temperature measurement was broken.

A velocity sensor was also flown in this sonde, but no data was received on air flow in the duct as the second thermistor was apparently inoperative, displaying a steady output. No velocity sensors were flown on later flights because air flow through the ducts was already evident and other data was considered more important. The elapsed time from announced cutdown until signal reception was approximately one minute.

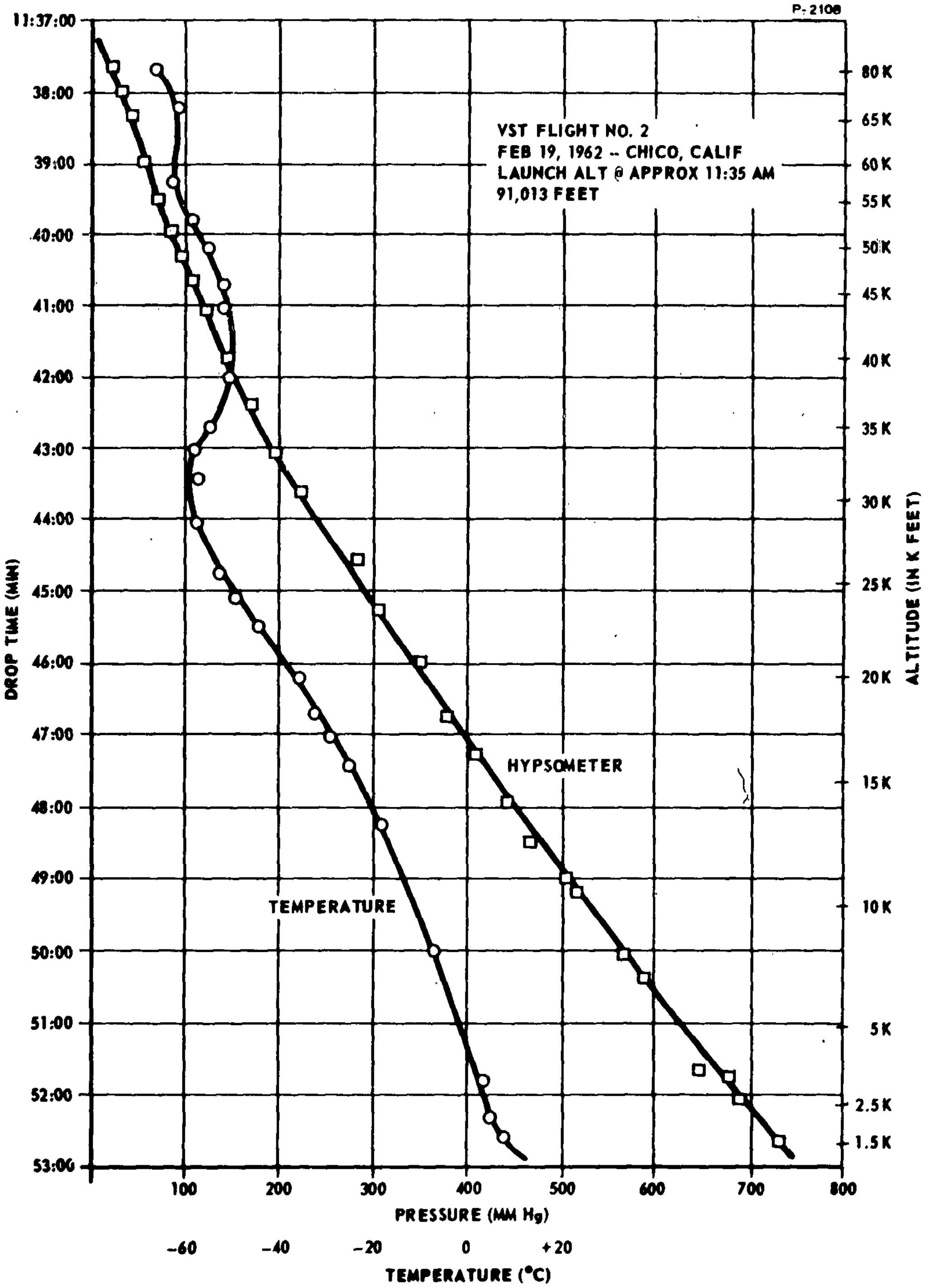


Figure 19 - Temperature-Pressure, Flight No. 2

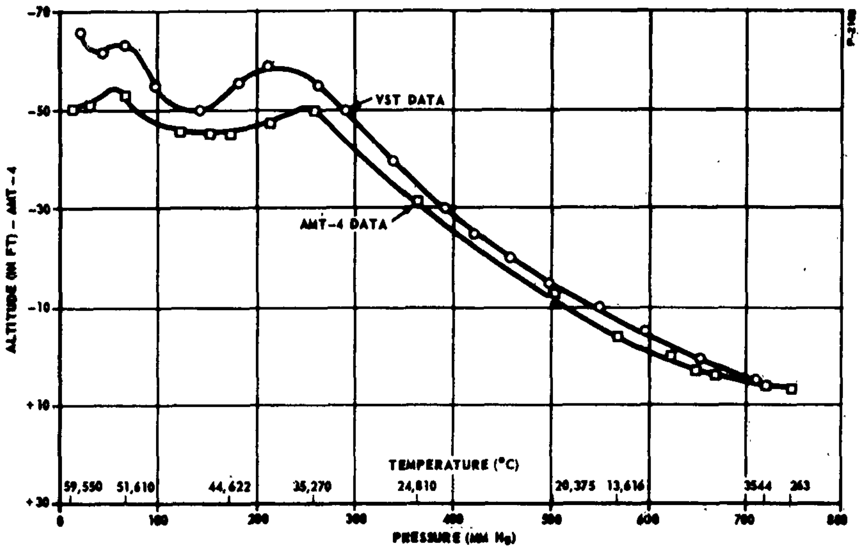


Figure 20 - Temperature-Pressure Comparison, Flight No. 2

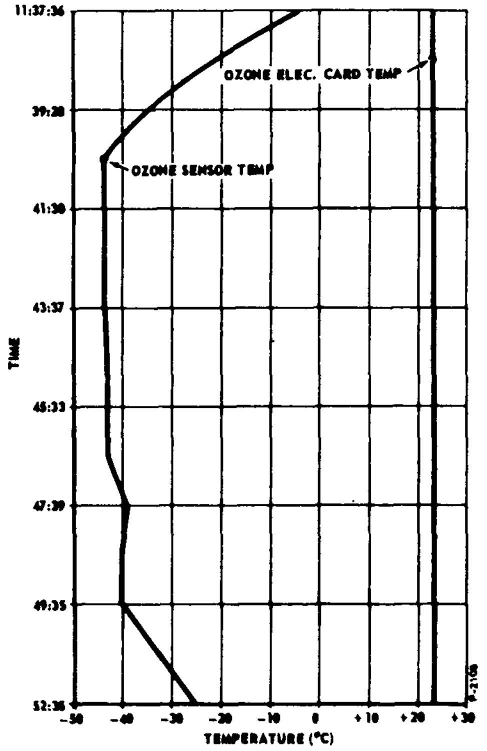


Figure 21 - Ozone Data, Flight No. 2

6.1.3 Flight No. 3

The balloon launch time for this flight was at 10:08 a.m., February 21, 1962. The sonde was dropped from an altitude of 90,361 feet at 12:35 p.m. The telemetry signal was detected at cutdown; however, within a short period of time, the signal strength began to fade until completely lost. Shortly after this loss of signal, it was detected again very weakly but increasing in strength until normal signal strength was reached and remained this way for the rest of the flight. During several instances, the identification frequencies appeared to either drop out or shift in frequency to an undetectable level but not for an extended duration. The following sensor outputs were monitored during this sonde flight:

1. Hypsometer
2. Hypsometer Heat Sink
3. Sonde Frame Temperature
4. Temperature Sensor
5. Ozone Sensor
6. Ozone Sensor Temperature
7. Refractometer
8. Exhaust Temperature
9. Temperature Switch Position
10. Carbon Humidity Element
11. Baro-Activated Pressure Sensor

The temperature data was reduced and determined to be in error for this flight. In the initial transmission, the indicated temperature was very erratic, oscillating from a positive to a negative value until after about three and one half minutes of drop time and stabilized at approximately -16 °C. A faulty thermistor or an improper solder junction are probable causes for the malfunction.

As the data for the hypsometer output was reduced, it was observed that this information was also in error. The indicated pressure started at an expected level; however, within a two minute period from sonde drop the indicated pressure became a steady output. At this point

the associated outputs that were monitored were investigated. The sonde frame temperature reading started a negative trend at this point as did the hypsometer heat sink temperature. It was concluded from this information that there was a malfunction in the hypsometer heater.

The index of refraction sensor was first flown in this sonde. The output data was gathered from the three output positions in the logic count down board. This count down board performs the function of reducing the frequency to a level compatible for transmission. It was expected from prior knowledge that the index of refraction would, once a reference point was established, increase with decrease in altitude. However, the data gathered shows a decrease in (n) units from the initial receipt of data to a point 6 minutes after drop. Then the (n) unit count starts increasing as expected. It is difficult to determine where the problem exists as the pertinent information such as pressure and temperature are missing on this flight. There is a possibility, assuming no drastic alteration in the temperature or pressure profile, that the thermal insulation material used on the sensor slipped out of place or the heaters failed, as this sensor is sensitive to thermal changes. The data from the index of refraction sample exhaust temperature sensor indicates a very high temperature at sonde launch decreasing with decrease in altitude to a point some 10 minutes after drop, where a temperature level was reached in the range expected. The B+ oscillator monitor in the index of refraction sensor indicates a curve similar to the sensor output but the irregularities do not occur at the same time interval. The B- oscillator monitor shows an increase in voltage similar to the B+ oscillator; however, still not corresponding to the index of refraction sensor output.

Data was gathered from the ozone sensor on this flight during the first minute of signal reception. However, due to the limited points recorded and the inconsistancy of these points, it is impossible to draw any firm conclusions with respect to the content of the data received (Figure 22). Information on the ozone sensor temperature was recorded indicating an average temperature of +24 °C which was not available due to a broken thermistor on the previous ozone flight.

6.1.4 Flight No. 4

The balloon was launched at 2:48 p.m., February 21, 1962. The cutdown time was 4:35 p.m. and the signal was picked up immediately. However, shortly after cutdown the signal became garbled

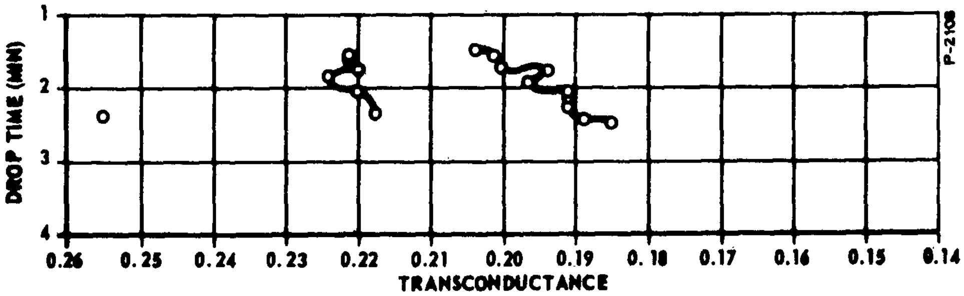


Figure 22 - Ozone Output, Flight No. 3

with identification signals out of their frequency ranges, and also loss of the 403 megacycle carrier, for a period of 3 to 4 minutes. Then the signal became stronger and back on frequency and remained this way. It was considered possible that corona in the transmitter at the high altitudes caused the loss of identification frequencies and the carrier as the transmitter used on this sonde differs from those before in that this transmitter contained no potting compound in the high voltage section of the R.F. amplifier. However, this was proven to be false with Flight No. 5 as the same problems occurred with a potted R.F. section. Below are listed the sensor outputs monitored on the flight.

1. Hypsometer
2. Hypsometer Heat Sink
3. Sonde Frame Temperature
4. Temperature Sensor
5. Refractometer
6. Exhaust Temperature
7. Temperature Switch Position
8. Dewpoint Sensor
9. Peltier Junction Voltage
10. First Frost Thickness
11. Second Frost Thickness
12. Peltier Heat Exchanger Temperature
13. Sample Tube Temperature

As the data was reduced on this flight it was apparent that there was a systematic error. The reference voltage, used principally in the error correction, was outside of its specified limits by such a margin that the next step was to analyze the battery voltage. It was shown that the B- voltage at the start of the flight was very low. This voltage finally came up to an acceptable level after 9 minutes of the flight had elapsed. It is believed the explanation for this is that the batteries could have been extremely cold at cutdown and the time that elapsed was required for internal heating by the batteries. As a result the data gathered prior to when the voltages reached their operating level cannot be used.

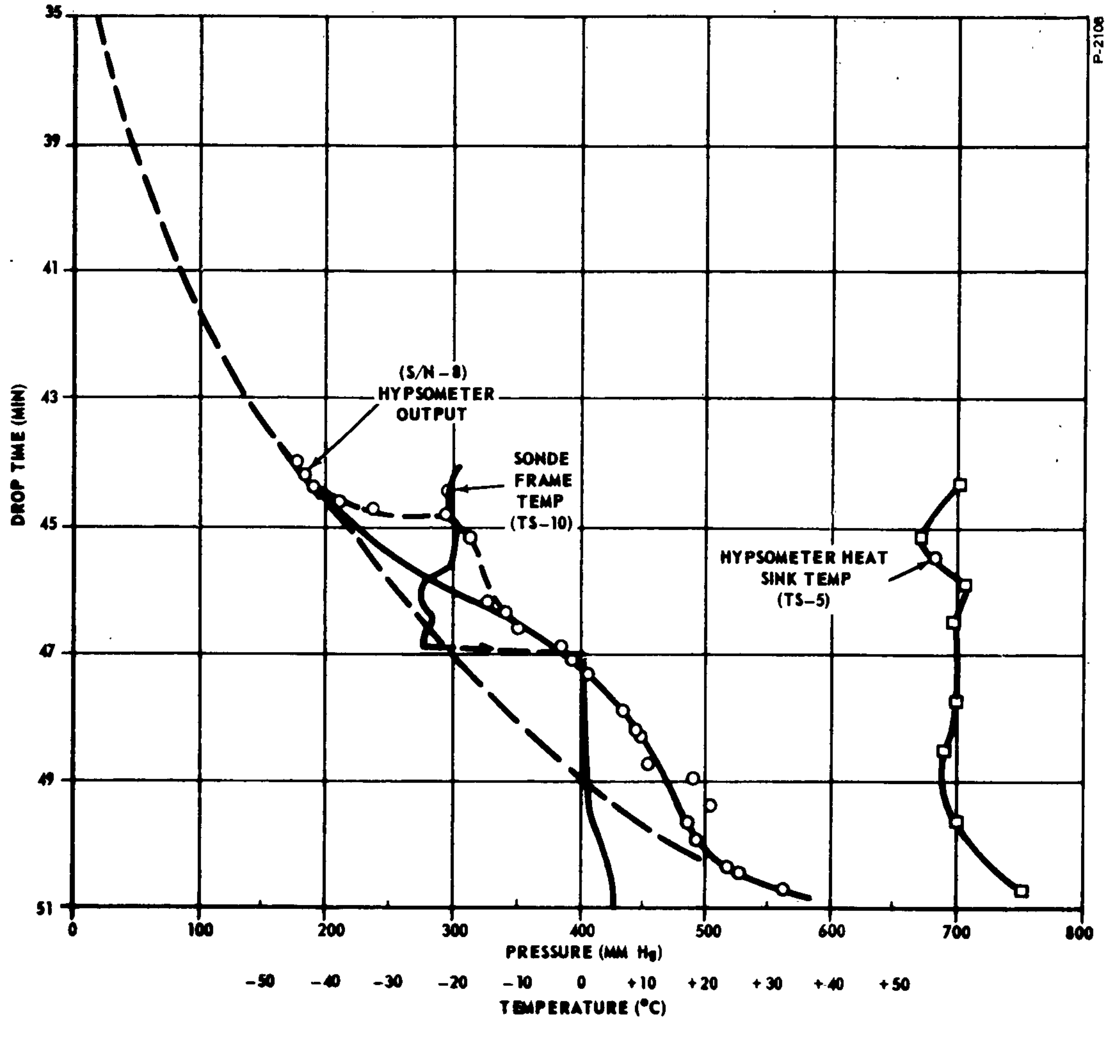


Figure 23 - Hypsometer Data, Flight No. 4

The data for the hypsometer pressure sensor (Figure 23) was the first to be reduced, but only that portion later in time with respect to the above mentioned voltage point. The remainder of the pressure profile received seems to be in agreement with those observed previously. The sonde frame temperature sensor data started at a point with a negative trend; however, after about three minutes there appeared to be a step change in output in the positive direction. From this point to the end of the flight the trend was positive as has been experienced before. There is at this time no explanation of what could have occurred to give the step change referenced. The hypsometer heat sink temperature was fairly constant until the last minute of flight data and then started to increase rather rapidly.

The data corresponding to the temperature sensor output (Figure 24) in general look similar to those reproduced on foregoing flights. However, there appears to be a discontinuity in the curve as

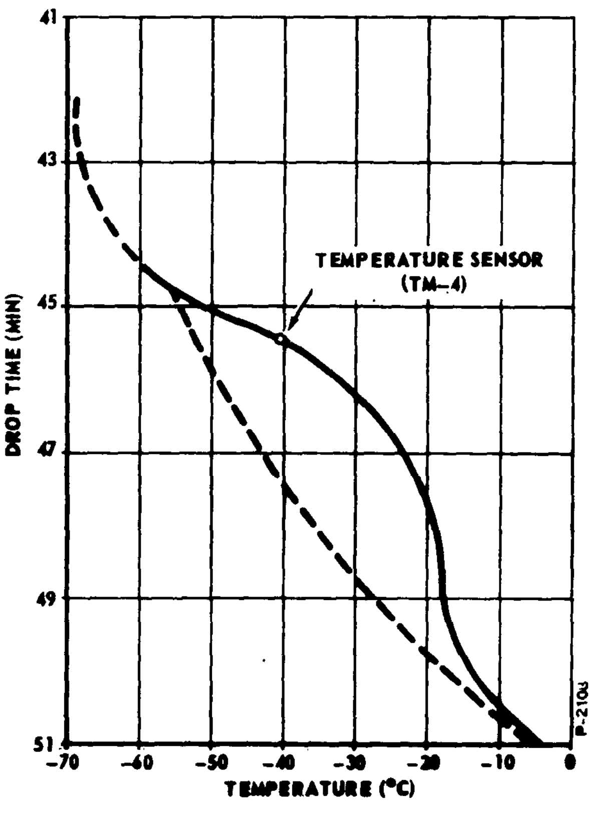


Figure 24 - Temperature, Flight No. 4

appears in the hypsometer curve starting after 10 minutes of elapsed flight time and settling out around 14 minutes after drop. There is a possibility that the low battery voltages at turn on produced a detrimental effect in the sensor electronics that cannot be compensated for with the applied error correction factor.

With both the temperature and pressure data available, a comparison chart was constructed with the AMT-4 data acquired on the flight ascent. It was observed that there was an offset of data points between the two with several irregularities in the VST sonde data. With an averaging curve drawn from the sonde data, the curve characteristics (Figure 25) are quite similar to those of the AMT-4.

This sonde contained the first dewpoint sensor flown on this project and the only one in which any data was received. As a preliminary measure to establish a reference profile the dewpoint temperature data at various altitudes was plotted using the information available from the AMT-4 during the balloon ascent. The data taken

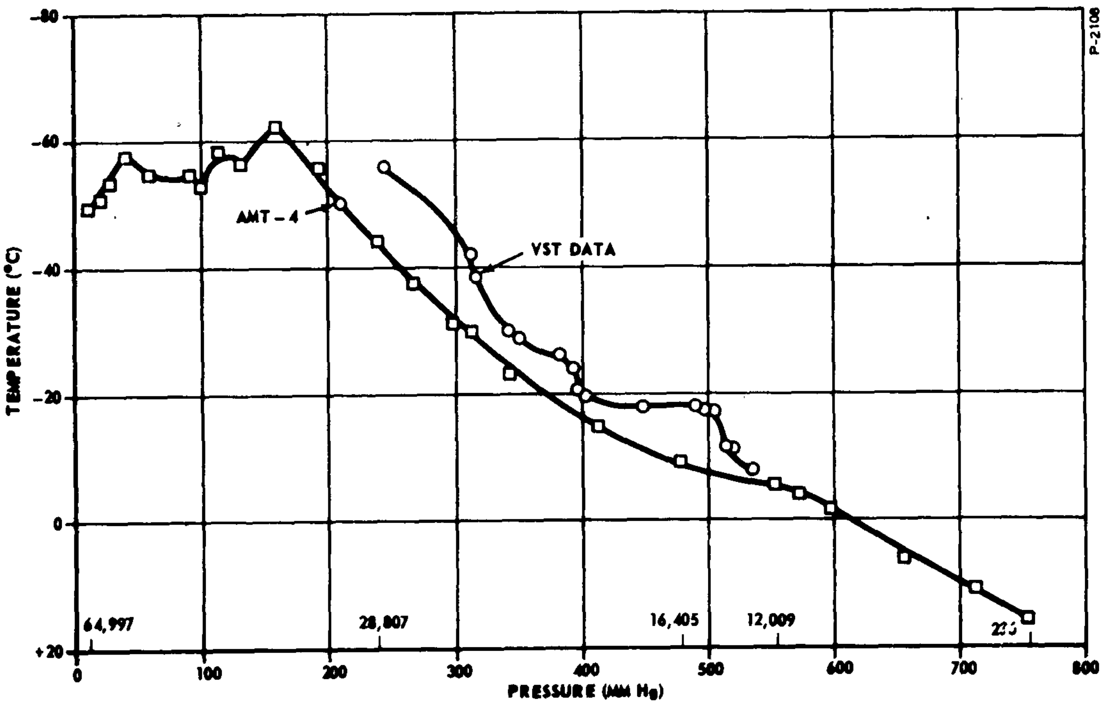


Figure 25 - Temperature-Pressure Comparison, Flight No. 4

from the dewpoint output shows an excessive amount of osciliation throughout the analyzed portion of the flight. However, an averaging curve constructed through these data points reveals a curve very similar to the AMT-4. The random oscillations observed in the initial data is believed to be a combination of effects. The data for both the Peltier junction voltage and the first frost thickness voltage during this same time interval experienced rather wild excursions. However, as flight time elapsed the oscillations in the first frost thickness data point settled out to a fairly constant output. From this point the excursions present in the dewpoint output were occurring in the same direction and time as those observed at the Peltier junction voltage monitoring point. The temperature points monitored in this sensor, such as dewpoint sample tube temperature, show a slight increase over ambient temperature, but the same general curve characteristics. The Peltier junction heat exchanger temperature again displays the same general curve with an increase in temperature above that of the sample tube temperature. This latter fact is rather disturbing in that in conjunction with design calculations and laboratory tests the thermal mass of the heat exchanger was sufficient to maintain a thermal lag with reference to the ambient temperature.

The index of refraction sensor on board this sonde indicates a curve more nearly normal than the first unit flown. As the reduced data was plotted, the initial 4.5 minutes appeared as could be expected. This was borne out by calculation of the index of refraction using the pressure, temperature, and dewpoint outputs of those sensors on board the flight. The slope of both of these curves are quite similar although displaced somewhat. The portion of the sensor output curve beyond the aforementioned 4.5 minute point has a rather large positive excursion encompassing some 480 N units within a period of one minute; then reversing for a negative excursion of 60 N units in less than one and a half minute. It would appear that this last one and a half minute of data was affected by something other than index of refraction changes.

The index of refraction exhaust temperature sensor for this flight indicated a low temperature at the initial point of the flight. At a point 12 minutes after launch an abrupt change was observed from a negative to a positive temperature reading. This change was also observed on the sonde frame temperature output. Both of these points are rather close on the commutator and could be the source of the problem as will be explained under the next flight heading.

6.1.5 Flight No. 5

This balloon was launched at 10:00 a.m., February 22, 1962. At 12:40 p.m. the sonde was cut down at an altitude of 89,213 feet. The transmission signal was picked up immediately but was very poor. The complement of monitored sensors on this flight are listed below.

1. Hypsometer
2. Sonde Frame Temperature
3. Hypsometer Heat Sink
4. Temperature Sensor
5. Ozone Sensor
6. Ozone Sensor Temperature
7. Ozone Electronic Card Temperature
8. Refractometer
9. Exhaust Temperature
10. Dewpoint Sensor
11. Peltier Junction Voltage
12. First Frost Thickness
13. Second Frost Thickness
14. Peltier Heat Exchanger Temperature

The index of refraction sensor output on board this sonde appeared to be on several segments of the commutator. A curve of the index of refraction sensor output was plotted (Figure 26) using the data received from this sonde and was shown to be very similar to that of flight number four, the main difference being that the slope was more gradual and always in the same direction. The signal received time was about 30 seconds after launch so the information gathered is over the entire drop profile.

At the termination of flight number five the sonde used on flight number two was returned to us by the local authorities. In an effort to determine why flight number five might have reacted as it did an investigation was conducted. It was found by looking at the commutator

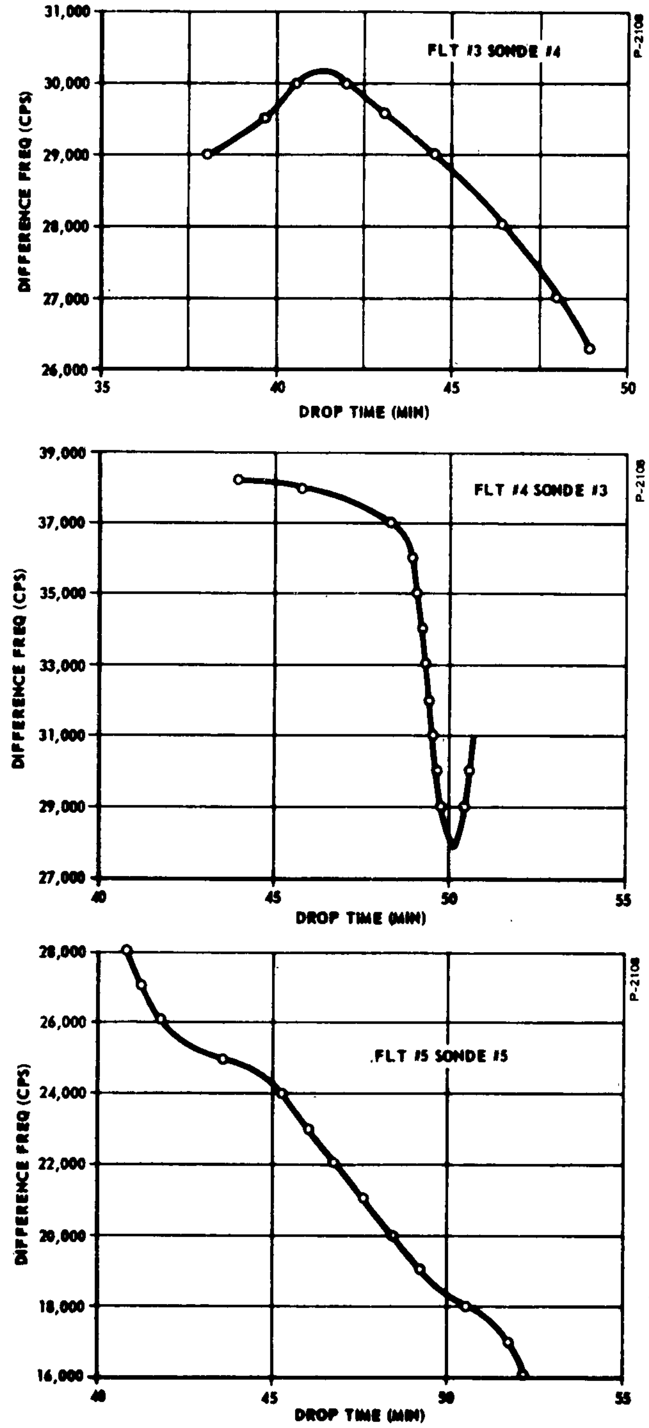


Figure 26 - Index of Refraction Output, Flight Nos. 3, 4, and 5

surface that there was a substance deposited over the entire board that appeared as if oxidation of the commutator material had taken place. On further investigation it was found that the water vapor given up by the hypsometer had condensed out on the commutator surface. This problem did not present itself so strongly in the first two flights as there was a baro-activated pressure sensor mounted in the space between these two devices. However, it does indicate why this pressure sensor did not function properly. In view of this event it can be seen that water on the commutator surface would afford many paths of continuity between the segments containing the data outputs. This, of course, would result in an uncorrectable error.

6.2 FLIGHT DATA SUMMARY

This section will be utilized in general to summarize the data gathered during the flight test. Instead of treating each flight individually, an attempt will be made to acquaint the reader with the functions performed by the sensors on board the sonde. In those instances where malfunctions were experienced an attempt will be made to analyze the problem for the possible source.

Each sonde that was flown contained a pressure measuring device or hypsometer. Of the six hypsometers that were flown, four of them provided information that is generally considered as being reliable (Figure 27). Of the remaining two hypsometers, it is believed that the one flown on flight number three experienced a malfunction in the heater. This was verified by the indications supplied by the associated points monitored within the hypsometer sensor. The remaining hypsometer output was not obtained due to an internal problem in the sonde affecting data transmission. It was learned, after the return of the sonde flown on the second flight, that the water used in the hypsometer had condensed out on the surface of the commutator. This conclusion was drawn by the evidence of what appeared as an oxide coating on the commutator board and was further confirmed by a second sonde recovered and returned at a much later date. As this information was available after the last flight was terminated, remedial action could not be taken.

It was observed in the instances of flights 1, 2, and 3, where a baro-activated pressure sensor was mounted in the area between the hypsometer and commutator, that all segments of the commutator were not equally exposed to the moisture-laden air. However, in no instance

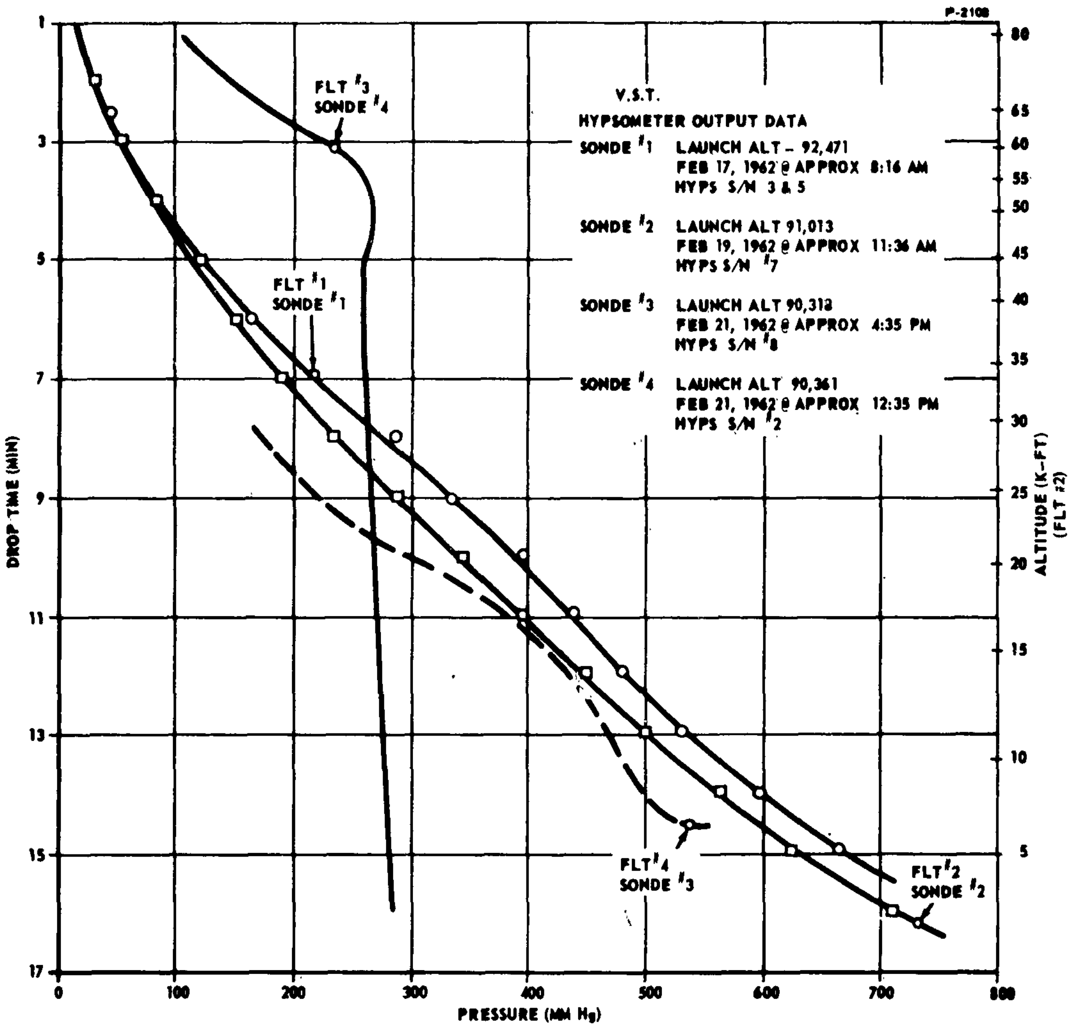


Figure 27 - Composite Graph of Hypsometer Output Data Flight Nos. 1, 2, 3, and 4

was a usable output from the baro-activated pressure sensor received. It appeared that the pressure sensor would begin to function and then produce a constant output, indicating that the wiper arm had stopped in one position of its travel. It was noticed that the areas of the commutator that were affected in these first three flights were the same even though flight number one contained two hypsometers. The segments of the commutator effected were 3B&C, 4A, B&C, 5A, B&C, and 6A&B. On some of these flights the information contained within these segments was not duplicated on other segments, and as a result were lost, for

example, the temperature data on flight number three. It could be seen after reassembling the commutator and baro-pressure sensor that the remaining segments of the commutator, not included above, are shielded by the frame of the baro-pressure sensor from the hypsometer. It is also conceivable that due to the lack of moisture at the altitudes flown, a high rate of evaporation was in existence, preventing the entire commutator board from becoming saturated, and not affecting all of the segments on the commutator.

The ozone sensor was flown in three of the sondes; however, no conclusive data was received. The first ozone sensor was flown on flight number two. The recorded output indicated that saturation of the film was attained shortly after sonde launch. Also, the output from the thermistor in the sensor sample chamber gave a reading indicating a very low temperature. As mentioned earlier, this was proven to be false because the thermistor was broken; however, at the time of the preliminary reduction of data, this appeared to be the cause of the sensor output indication of saturation. On the second ozone flight the output also indicated saturation within the first minute of flight. This output appeared at two different points on the commutator; however, one of these points fell in the section of unreliable data so cross correlation was impossible. Using the other output, a limited number of points were available but, due to the amount of data received and the non-uniformity of these points, it was considered impossible to use this information as an indication of ozone concentration. With the knowledge and experience gained on the first two flight of ozone, the decision was made to extend the sensitivity of the film for the third flight anticipating that this action would prolong the time duration between sonde launch and film saturation. This unit was flown on flight five in which valid information was gained for the index of refraction sensor only.

The index of refraction sensor was flown on three flight. On flight three, the output started out very erratic and as the flight progressed, both positive and negative slopes were observed in the curve. The possibility exists that the effects of moisture and temperature variations within the sonde produced the irregularities observed in the output. The index of refraction sensor flown on flight number four produced an output at the onset of the reliable portion of the flight simular to what would be expected. However, after a period of three to four minutes from this point, a large positive excursion was experienced, then reversing for a negative trend. On this flight there was sufficient

information available from the other sensors on board to plot a curve of calculated index of refraction data. These two curves are quite similar during the period immediately after the battery voltage attained the correct level, but the calculated data produced no large excursions. Here again the abnormalities experienced in the sensor output may have been caused by the sudden moisture or temperature fluctuations. The index of refraction sensor on flight number five was the only data received from this flight. This curve, when plotted, appeared more realistic than any of those seen previously; however, no additional data from this flight was received to substantiate it. During the duration of flight five it was noticed, from the audio presentation of received data at the ground station, that the index of refraction data was being presented on more than its assigned channels, and at random intervals. Upon the investigation of the control circuitry it was determined that this could occur if the gating control voltage dropped in amplitude 4.0 volts. This would require that the gating control circuit see a source impedance of approximately 2200 ohms. Without getting too involved in the transmitter circuitry, the normal sequence for activating this control circuit is in the application of a ground potential at the control gate by the commutator. When this ground potential is applied, the transmitter oscillator is then driven by the index of refraction outputs. It is reasonable to assume that the problems on this flight were caused by the condensation of water vapor on the commutator. However, it does not necessarily mean a leakage to ground occurred. It is quite possible that a leakage path to another value segment could just as well have been the source of trouble for the random transmission of this data, for most of the other output circuits would either present an impedance equal to or less than the 2200 ohm impedance required to trigger the index of refraction gates. After this control circuit has been triggered, the position of the wiper arm on the commutator is no longer of any significance for the output of the index of refraction will override any other value signal present.

The data output from the dewpoint sensor was not received for the reasons stated above on flight number five. However, on flight number four an output was recorded after the battery voltage came up to the correct level. As this data was plotted, it was revealed that the output was experiencing rather large oscillations throughout the acceptable portion of the flight. As a method of determining the probable cause of these oscillations, the data on the frost thickness and the Peltier junction voltage outputs were plotted. It was seen that at the beginning both of

these were also oscillating very erratically. However, after a short period of time the output from the first frost thickness steadied to a point where even though the oscillations were still present, their amplitude was very small. The Peltier junction voltage remained in oscillation for the entire flight and it was observed that the dewpoint output data, having the nearest time relation to that of the junction voltage, followed these oscillations. As a means of checking the dewpoint output, an averaging curve was drawn through the plotted points. This then was compared with a curve of dewpoint temperature received from the AMT-4 sonde that gathered data during the balloon ascent. These two curves did display the same characteristics at approximately the same points with respect to altitude.

The AMT-4 weather sonde mentioned above was flown on each flight, but gathered data only while the balloon was ascending, whereas the V.S.T. sonde gathered data during the descent by parachute. Each flight where a sufficient amount of data was gathered by the V.S.T. sonde, a pressure-temperature curve was constructed and compared with a pressure-temperature curve from the AMT-4 used on the same flight. In each instance both curves matched very closely.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations included in this section will treat each sensor separately, including the data transmission and processing equipment. The sensors developed on this program were designed with the capabilities of operating in a balloonborne dropsonde from an altitude of 100,000 feet to sea level.

7.1 CONCLUSIONS - HYPSOMETER DEVELOPMENT

The hypsometer flight test data was considered very good. As no independent method was employed for sonde tracking such as radar ranging, etc., there was no means of altitude-pressure correlation, unless the I.C.A.O. data tables are used. Hence, the factors of prime importance in analyzing the quality of the hypsometer performance in each flight were the continuity of its output and the adherence to a smooth rate-of-change of pressure with drop time.

The data gathered from sonde flights one and two indicate a successful performance over the complete range and are presented in a smooth and continuous manner. The hypsometer on sonde flight number four appeared to operate successfully over the time interval in which data was received (data was not obtained during the initial portion of the drop). The data from the hypsometer on sonde flight number three indicated abnormal conditions. However, on the basis of the hypsometer output and the auxiliary measurements, such as heat sink temperature and sonde frame temperature, it is assumed that there was a failure in supply power for the instrument during the descent.

On the basis of the previously discussed test results, it is concluded that the hypsometer developed has proven completely satisfactory for this method of measurements.*

*Very successful flight tests were conducted on this hypsometer using the ARCAS - AN/DMQ-9 rocketsonde at Eglin Air Force Base by the Bendix Friez Instrument Division and the AFCRL in 1963 and have substantiated this conclusion.

7.1.1 Recommendations - Hypsometer Development

The hypsometer developed for this program was designed to provide pressure measurements over the range from 220,000 feet to sea level. However, it has only been flight tested from approximately 100,000 feet to sea level. It is recommended that the full operational capability of the instrument be demonstrated by conducting tests in the 200,000 foot altitude range with the use of sounding rockets.*

The performance limits of this instrument have not yet been fully explored. It is recommended that requirements for soundings with characteristics of wide dispersal of maximum altitudes reached and largely deviant drop velocity profiles should be examined. It is further recommended that an extension of the capabilities of this particular hypsometer be examined along with the general techniques for use in higher altitude soundings in the 300,000 to 400,000 foot range.

A description of specific technique recommendations may be found in the document entitled "Development of a Hypsometer for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 2056.

7.2 CONCLUSIONS - OZONE SENSOR DEVELOPMENT

The data received from those sonde flights containing ozone sensors gave an indication of much higher concentrations than anticipated. The fact that the response received was in a positive direction indicates that the sensor was working; however, the rate of change was much greater than expected and far in excess of calculated data. The lack of a check point on the sensor output prior to the drop time and the possible presence of atomic oxygen at the drop altitude, in conjunction with the limited data points and initial transmission problems, makes drawing definite conclusions very difficult.

For further information related to this sensor, reference is made to the document entitled "Development of an Ozone Sensor for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 1998.

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*See footnote previous page

7.2.1 Recommendations - Ozone Sensor Development

It is recommended that additional development be considered on this sensor for an analysis of the constituents at the higher altitudes. Since the closing of the flight tests on this program the Bendix Research Laboratories Division has done considerable developmental study and fabrication of sensors utilizing thin film technology. The output of these efforts has been very encouraging and has resulted in fabrication of devices for sensing the presence of several gases in the parts per million concentration.

It is believed that additional laboratory and flight testing, for verification of performance characteristics of this sensor for oth ozone and atomic oxygen, would result in a useful instrument.

7.3 CONCLUSIONS - INDEX OF REFRACTION SENSOR DEVELOPMENT

A plot of the index of refraction data from sonde flight number three (Figure 26) shows an initial increase in frequency which corresponds to an apparent decrease in index of refraction. There is evidence that the temperature of the sonde at the time of drop was much higher than the ambient temperature of its surroundings, and that the temperature of the sonde decreased as the drop progressed. Due to the temperature sensitivity of the coil in the sensing oscillator tank circuit, the initial increase in frequency is considered due to the reduction in temperature of the coil

The data gathered on flight number four was considered to be of little value due to main battery failure. As a result, no conclusive evidence was obtained on the operational performance.

The data gathered from flight number five closely resembles that obtained in the environmental test chamber from laboratory tests conducted prior to the flight test phase of the program. The output frequency decreased by an amount greater than that accountable for by change in index of refraction. The error again is ascribed to an increase in the temperature of the coil during descent. From previously recorded test data a temperature increase of 10°C in the vicinity of the coil is required to produce the observed error; it can be concluded that during a sonde drop a temperature rise of this magnitude is quite possible.

For further information concerning this sensor, reference is made to the document entitled "Development of an Index of Refraction Sensor for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 2057.

7.3.1 Recommendations - Index of Refraction Sensor Development

The results of the sonde flight test program re-emphasizes the need for increased thermal stabilization of the sensing oscillator circuitry. A combination of closer temperature control and electronic compensation should result in much improved accuracy of the refractometer when it is operating in an environment of rapidly changing temperatures. It is recommended that further development of this instrument along these lines be continued.

Since the Vertical Sensor Techniques flight test termination, an improved design of the "monolithic" structure has been developed. This design has resulted in much better shielding of the sensitive electronics to external radiation and made possible the use of proportional temperature control using conventional heaters. This form of temperature control was employed in a refractometer designed to operate in an ascending balloon, where use of control methods similar to those of the V.S.T. program was impractical. This ascending balloon sampling version of the refractometer displayed a temperature coefficient of about 4 ppm/°C. Through experimentation with electronic temperature compensation it has been shown that this coefficient can be reduced by an order of magnitude.*

With the recent availability of high frequency silicon transistors the development of a transistorized refractometer operating in the UHF region has been made possible. The output of a sensing oscillator operating at, for instance, 400 megacycles can be amplified and applied directly to the sonde transmitter, eliminating the need for the reference oscillator, mixer, and count down circuitry as used on the V.S.T. model. Recent developments at the Bendix Research Laboratories Division, using 2N918 transistors, produced an operating breadboard model of a 400 megacycle sensing oscillator and amplifier package with dimensions less than 6" x 2" x 2". The

*Operation Manual for Refractometer Developmental RCAB-1, Report No. 2175.

sensing device employed is a folded coaxial resonator which is a small volume, high Q device. In addition it appears possible to achieve a very low temperature coefficient in the folded coaxial resonator by using a self-compensating design paralleling that of the V.S.T. sensing capacitor. Initial tests have shown a high basic stability and a linear dependence of output frequency on index of refraction.

7.4 CONCLUSIONS - HYGROMETER SENSOR DEVELOPMENT

The formulation of conclusions from the data received on this sensor is extremely difficult due to the limited amount of data gathered. This sensor was flown only once where any data was recorded, and for the greater portion of this flight the battery voltages were well below design levels, which makes accepting this information questionable. The frost thickness monitor produced an output corresponding to nearly 50 percent frost thickness, an excessive value. However, this was not substantiated by the remaining outputs. The oscillatory condition observed in the basic sensor output was believed to be caused by either light reflected from clouds below entering the mirror assembly or turbulent air flow in the sample inlet. Both conditions are easily corrected in a better sonde design.

7.4.1 Recommendation - Dewpoint Indicator Sensor Development

It is recommended that further tests be conducted on this instrument so that its operational performance as an atmospheric sounding device may be determined.

Since the termination of the V.S.T. flight test phase, two models of a Peltier controlled dewpoint hygrometer for laboratory use have been developed. The accuracy and stability of these units have been excellent, demonstrating the feasibility of utilizing this method for determining dewpoint.

For further information concerning the development of this instrument, reference is made to the document entitled "Development of a Dewpoint Hygrometer for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 2055.

7.5 DATA TRANSMISSION AND PROCESSING EQUIPMENT

The residual inventory equipment from the AN/AMQ-15 Air Weather Reconnaissance Program made up the major portion of the

ground receiving and data processing equipment. It can be concluded in general, that this modified equipment performed well within its intended design capabilities. However, in the flight test phase, the complexity of the commutation scheme, due to the many test points monitored, did not allow uniformity in data acquisition. As an illustration, the C level of value data corresponding to each identifier was stored in the output register of the sonde decoder, while the values of the A and B level remained for only an instant. In some cases, due to sampling interval, one or the other of these two data points were not recorded. It is believed that this situation would have improved considerably as the individual sensors proved themselves had more sonde flights been conducted.

SECTION 8

REFERENCES

1. "Development of an Index of Refraction Sensor for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 2057.

2. "Development of an Ozone Sensor for Atmospheric Sounding," AFCRL Technical Note, Bendix RLD Report Number 1998.

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